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Increasing the Electrical Vehicle Efficiency with Genetic Algorithm

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Abstract

The efficiency of electric vehicles is becoming more and more important every day. Accurate determination of the speed values that the electric vehicle driver has to go at different slopes of the road route enables the electrical vehicle to be used more efficiently. Inefficient use of vehicles with different slope values of the road compared to engine characteristics increases energy consumption. There are many algorithms used for optimizing the solution. Genetic algorithm which produces effective results by using crossover and mutation operators is widely used in the literature.

In this study, with the help of genetic algorithm, it was tried to find the optimum speed values which can provide reaching to the target in the desired time by consuming the least amount of energy in the road routes with different slope values for electric vehicles. For this purpose, Hub engine consumption characteristic which is widely used in electric vehicles is transferred to software environment. In addition, a sample route of approximately 2 km in length is determined and the coordinates of the route and the slope values in the ArcGIS software environment of Geographic Information Systems are processed in different layers and transferred to the software environment.

A software that uses the Genetic Algorithm functions by reading the specified road and motor characteristics from two different text files and providing the user with the best results from the alternatives has been realized with the help of C# programming language in Visual Studio environment. The developed software will provide the basis for future vehicle efficiency studies, while allowing electric vehicles to go longer.

Keywords: Electric vehicles, driving optimization, genetic algorithm.

1. INTRODUCTION

Electric vehicles (EV) are more environmentally friendly than internal combustion engine (ICE) vehicles and are highly interested in the potential for depletion of oil resources over time. They have a simpler motor structure than ICE vehicles, which is why EVis preferred. However, the main disadvantage of EV is that the battery capacities that will feed electric motor systems are lower than the ICE vehicle ranges at the given kilometer.

In order to solve this problem, efficiency is very important in EV. Keeping at the highest levels of efficiency will reduce the energy consumption to the minimum at EV, so the range of vehicles will be even longer. Increase efficiency in EV battery, motor, communication, mechanical parts, shell and so on. As well as by optimizing the vehicle driving according to the road conditions. One of the road conditions that affect energy consumption is the road gradient. Determining the ideal speed relative to the curve will significantly reduce energy consumption, allowing the EV to go longer distances.

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2. RELATED WORKS

Some recent literature in the literature is as follows to increase efficiency in EV. In [1], an optimization method has been developed using indirect optimization method for serial hybrid EV. In the developed method, the speed of the vehicle was adjusted in consideration of the time, safety and comfort criteria and a decrease in energy consumption was recorded.

In [2], a simultaneous optimization was performed with the help of multi-objective evolutionary optimization tools using the powertrain and driving strategies for Hybrid EV. In order to ensure economic driving of Hybrid EV's in operation, it is emphasized that the correct selection of power transmission elements, such as the right gear range selection, as well as the correct selection of the driving strategy.

In [3], a system has been devised so that the correct measurement of the energy consumed in the EV, the first step in the EV's energy consumption reduction efforts, can be made. Five-month EV consumption values were measured and EV's consumption characteristics and performance were removed. An analytical EV power estimation model has been developed in the light of these values.

In study [4], the driving range was optimized for EV drivers in the USA, taking into account the battery charge, electricity charge and other factors limiting the range.

3. MATERIALS AND METHODS

In this study, the following steps were followed in EV to determine the least cost velocity values of the vehicle according to different slope values in the road route.

• The Hub engine consumption characteristic, which is widely used in EV, has been obtained. For this, all measured values are transferred to the digital medium by making measurements for the EV to be used in the operation at different slope and speed values.

• A sample route with different slope values has been determined and the digital coordinates have been transferred so that the coordinates and slope values of this route can be applied to the optimization study.

• In Visual Studio environment, using C # programming language with Genetic Algorithm, speed alternatives that can be traversed in intervals with different slope values of the route with the goal of reaching the target in the desired time and comparing the total average values of energy consumption are selected and the best solution is selected by testing all variations.

• It is given to the user which average speed value should be taken on the route within the given solution range.

Fig. 1 shows the intervals with different slope values in a sample route. EV can go at the desired speeds at these intervals. However, in order to be able to find the speed values at which the target can be reached at the desired time with minimum energy consumption, thousands of alternative values should be passed through and tested.

In this study, genetic algorithm is used to find the most suitable value speed values.

Fig. 1. Intervals having different slope values in a sample route.

3.1. Genetic Algorithm

GA is an optimization algorithm originally developed by J. Holland in 1975 with functions such as the generation of new individuals from randomly selected individuals in a population, the survival of the best of the produced individuals, the exchange of newly produced individuals. The flow diagram of the genetic algorithm is shown in **Fig.2.**

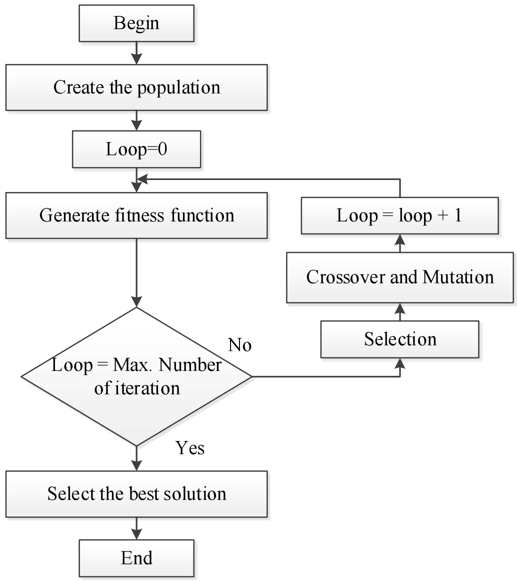


Fig. 2. GA flow diagram.

In GA, the chromosomes that make up the community are made up of genes. Each gene carries the properties of chromosomes that represent alternative solutions in optimization studies. Crossing and mutation are functions that are applied to find better solutions. The new generations are the individuals obtained by making changes on the two selected individuals [5, 6]. The reason why the genetic algorithm is a common and widely used algorithm is that it has a powerful best search mechanism using simple calculation [6].Assuming that each route is a chromosome in route studies, the pixel values of this route are expressed in GA by genes.

3.1.1. Generating the population

A set of solution expresses the possible solutions to solve the problem. Each individual in the solution set is also called a chromosome. Identification of the individuals in the solution set is very important. No definite judgment has been made for the size of the solution set to be solved for different problems [6]. When this value is too small, the algorithm is not able to find a good solution as a result of reducing the number of alternatives needed to find the best solution. The fact that the number of individuals in the solution set is too large also appears to be an effect that slows down the algorithm considerably. The best value should be determined by the behavior of the problem [7].

3.1.2. Generating the fitness function

The fitness function shows how good the chromosomes in the community are. This function is very important for GA because the selection process in GA is done according to the fitness function.

3.1.3. Selection

It is the choice of two chromosomes from the population, taking into account their fitness values (so that the likelihood of better fitness is high). Commonly used selection methods are roulette wheel selection, tournament selection and sequential selection.

The choice of roulette wheels is related to the area covered by the suitability values of the individuals in the solution set. Thus, there is a chance of being elected to unhealthy individuals. The probability of selecting each individual in the community is calculated by calculating the ratio of the individual's fitness values to the sum of the fitness values of the individuals in the community. The goodness of the individual's eligibility values increases the likelihood that individuals will be selected from within the solution set [6]. In the sequential election, the individual with the worst eligibility value is given 1 value, the better one is given 2, the better 3 is given. The probability of selecting individuals is the ratio of the values given to the individuals to the sum of the values given to all the individuals. The aim here is to enable individuals with low fitness values to be chosen. In tournament selection, some individuals are randomly selected from within the community. From these selected individuals, the best fit value is selected. Community size should be considered when determining the number of individuals to be elected. The aim is to increase diversity by making use of random selection [5]. The most widely used method of selection is roulette wheel selection [6].

3.1.4. Crossover

Crossover, which is the most effective part of GA, is the formation of better individuals by mutual exchange of the characteristics of selected individuals.

3.1.5. Mutation

It is the identification of better individuals by changing the chromosome structure of the individuals to be transferred to the next generation from the individuals in the solution set. Mutation is achieved by ensuring diversity by preventing new solutions from copying the previous solution and ultimately achieving faster results [5].

4. RESULTS AND DISCUSSION

In this study, the following steps were carried out in the electric vehicle (EV) to determine the least costly speed values according to different slope values on the road route.

In EV, it was tried to remove the widely used Hub engine consumption characteristic. For this, the characteristic curve shown in **Fig.** 3 of the sample electric vehicle hub motor used in Gumushane University is used. The vehicle model calculations for removing the consumption values of the used electric vehicle are as follows.

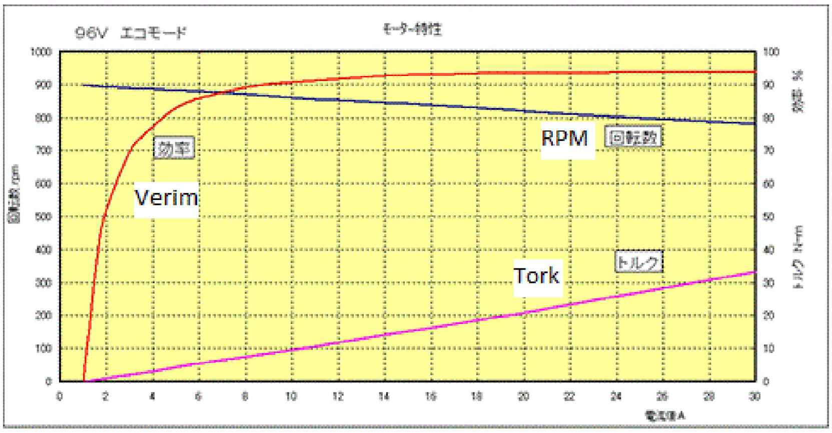


Fig. 3. Mitsuba M2096II Hub engine curve.

4.1. Computation of Resistance Force on Vehicle

In any electric vehicle, resistance forces are generated in the opposite direction to the direction of travel of the vehicle. These forces are; Aerodynamic (air) resistance, rolling resistance, slope resistance, acceleration resistance.

The air resistance varies depending on the relative speed of the vehicle and the wind. The rolling resistance depends on the friction between the tire and the asphalt and does not change depending on the speed. Slope resistance depends on the incline value of the slope which the vehicle is climbing. Acceleration resistance is a variable resistance depending on the vehicle's acceleration and effective mass.

The vertical surface area of the electric vehicle used in this study in Gumushane University is calculated from the three-dimensional drawing of the vehicle as 1.57 m^2. The air density ρ is taken as 1.255 Kg/m^3, the drag coefficient C_D is taken as 0.229. As it can be seen, the increase in vehicle speed increases wind resistance. As wind resistance increases with speed, fuel consumption increases at high speeds.

Rolling resistance has been neglected in the subtraction of engine consumption characteristics of the electric vehicle because it does not change with the speed of the vehicle or the slope of the road.

The weight of the electric vehicle used in the study was measured as 280 Kg. This value will be used to add variable slope resistance according to the road slope of the vehicle.

In this study, it is assumed that the EV has determined the least costly speed values according to different slope values in the road route, the vehicle is traveling at constant speeds at different slope intervals, ignoring the acceleration resistance. Also, the resistance values of other mechanical components are neglected because they do not change very much with vehicle speed and slope value. In this case it is assumed that EV is exposed to air resistance and slope resistance.

4.2. Finding Road and Vehicle Characteristics

Current values drawn at different torque values from the consumption curve of the Mitsuba M2096II Hub motor used in the vehicle are transferred to the programming environment via the text file shown in **Fig.4.**

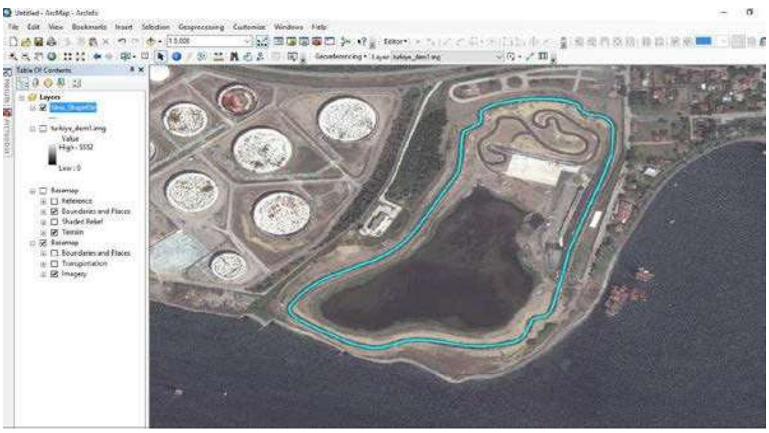
Karakteristik - Not Defteri

Dosya Düzen Biçim Görünüm Yardım

	1,388888889	2,777777778	4,166666667	5,555555556
-3	-32,61796289	-32,3064668	-31,78730664	-31,06048243
-2,9	-31,49487968	-31,18338359	-30,66422343	-10,40850133
-2,8	-30,37169717	-30,06020108	-29,54104092	-9,285318824
-2,7	-29,24841878	-28,93692269	-28,41776253	-8,162040433
-2,6	-28,12504793	-27,81355184	-27,29439168	-7,038669584
-2,5	-27,00158805	-26,69009195	-26,1709318	-5,915209699
-2,4	-25,87804255	-25,56654645	-25,0473863	-4,7916642
-2,3	-24,75441486	-24,44291876	-23,92375861	-3,66803651
-2,2	-23,6307084	-23,3192123	-22,80005215	-2,544330051
-2,1	-22,50692659	-22,1954305	-21,67627034	-1,420548246
-2	-21,38307286	-21,07157677	-20,55241662	-0,296694518
-1,9	-20,25915064	-19,94765455	-19,42849439	0,827227708
-1,8	-19,13516334	-18,82366724	-18,30450709	1,95121501
-1,7	-18,01111438	-17,69961829	-17,18045814	3,075263963
-1,6	-16,8870072	-16,57551111	-16,05635096	4,199371144
-1,5	-15,76284522	-15,45134913	-14,93218897	5,323533128
-1,4	-14,63863186	-14,32713576	-13,80797561	6,44774649
-1,3	-13,51437054	-13,20287445	-12,68371429	7,572007807
-1,2	-12,39006469	-12,0785686	-11,55940845	8,696313654

Fig.4. Representation of Mitsuba M2096II Hub motor in the text file of current values taken at different torque values.

A sample route of about 2 km in length is specified. The coordinates of the route and the slope values in the ArcGIS software environment of Geographic information systems are processed in different layers as shown in **Fig. 5.a** The processed data is transferred to the outside via a text file shown in **Fig.5.b.**



0	-0,048000	644171,561700	4928578,622400
1	0,049000	644183,274900	4928626,459200
2	0,049000	644201,475600	4928671,198700
3	0,049000	644225,535600	4928730,729300
4	0,310000	644246,816200	4928782,857000
5	0,310000	644268,224300	4928843,708800
6	0,310000	644271,930700	4928876,066700
7	0,310000	644273,800200	4928901,768900
8	-0,142000	644270,024900	4928917,034500
9	-0,142000	644262,645100	4928926,525200
10	-0,142000	644249,651000	4928932,324100
11	-0,142000	644234,995400	4928935,030200
12	-0,142000	644224,691500	4928940,299700
13	-0,142000	644218,477200	4928948,939400
14	-0,142000	644214,166900	4928959,469400
15	-0,142000	644200,347600	4928966,896400
16	-0,142000	644185,168000	4928971,215700
17	-0,142000	644164,170300	4928973,837500
18	0,035000	644137,393600	4928975,553600
19	0,035000	644108,955500	4928974,177000
20	0,035000	644080,603800	4928968,431100
21	0,035000	644058,496700	4928960,790200
22	0,035000	644046,947000	4928953,025800
23	0,035000	644044,769800	4928945,593300
24	0,035000	644045,126700	4928934,464300
25	0,035000	644042,191300	4928923,894400
26	0,035000	644030,078300	4928916,951500
27	0,035000	644020,131500	4928911,092400
28	0,035000	644013,234500	4928905,876600

(a) (b)

Fig.5. (a) Processing the coordinates and slope values of the route in different layers with ArcGIS software environment from Geographical information systems, (b) Transferring processed data to a text file.

4.3. Software Development

With the help of C # programming language, a software has been developed so that the characteristic values of the vehicle can be read in the programming environment and the genetic algorithm can be used.

The reading of the file containing the route coordinates and the slope values previously transmitted to the text file with the "Read the Route Path" button of the developed interface is provided

Vehicle characteristic values showing the current values of the motor according to the speed of the electric vehicle and the slope value of the road are memorized by means of the "Read Vehicle Character" button.

The information about the completion time of the route and the number of laps to be taken by the vehicle is entered into the program interface so that the algorithm can be operated according to these limit values.

With the "Calculate" button, the program tries to find the most appropriate speed values by using the above mentioned path and tool parameters and genetic algorithm.

The fitness function of the genetic algorithm used in this study is calculated as the sum of the multiplying of different slope valued parts of the path and the current values of the path of the vehicle.

Using the genetic algorithm, the interface was run at different times and the results were saved externally in the text file. In order to test the accuracy of the obtained optimum speed values and total CurrentxSecond values, it is assumed that the electric vehicle is traveling at an average constant speed and the values obtained at these constant speed values are compared with the values obtained from the interface.

In the first comparison, the current values and the time values that the electric vehicle consumed at different slopes of the road assumed to travel at a constant speed of 30 km/h by the driver were compared with the best values found by the algorithm. In the first case, it is required that the user who is 1.8 km long finishes in 5 min. In this case, the driver completed a course in 3.6 minutes.

In the second comparison, it is assumed that the electric vehicle travels at a constant speed of 50 km/h by the driver. The current values and the time values, which are drawn at different slopes of the road, are compared with the best values found by the algorithm. In the second case, a 1.8 km racecourse user is required to finish the course in 5 min. In this case, the driver completed theracecourse in 2.16 minutes.

The default values in the first and second comparisons and the values found by the software proposed by the Genetic Algorithm are given in **Table I**.

Table I. Comparing the values found with the software.

Comparison Number	Speed Value	Getting to target status at the desired time	Total Current x seconds Value (A.xSc.)
1. Comparison	30 km/h	Yes	1186,62
2. Comparison	50 km/h	Yes	1572,1
Developed Algorithm	Variable by slope	Yes	389,57

If the values in **Table 1** are compared, it is seen that it is possible to determine the speed values which consume less energy in the different speed values by the developed algorithm. It is not possible for the human brain to calculate the speed at which the driver should travel with minimum energy expenditure on the road during driving.

5. CONCLUSIONS

This study shows that longer distances can be covered with less energy consumption under variable road conditions. It has been presented that the developed algorithm has found the most suitable values by trying different variations according to the vehicle engine characteristics in different parts of the road and it enables them to go to the longer range with the current battery of the vehicle.

In the course of this work, real-time values are taken from a sample electric vehicle to make comparisons at longer distances, and the performance of other algorithms is planned to be compared with Genetic Algorithm.

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