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Construction of the electric vehicle driving support system considering the personal driving characteristics using geographic information system

Shuntaro Nakayama[a], Hiroki Iwai[a], Thongchart Kerdphol[a], Atsushi Shiota[b], Yasunori Mitani[a]

[a] *Kyushu Institute of Technology, 1-1 Sensui-cho, Tobata-ku, Kitakyushu City, 804-8550, Japan*
[b] *Kitakyushu City Office, 1-1 Jonai, Kokurakita-ku, Kitakyushu City, 803-0813, Japan*

Abstract

Recently, motor companies focus on the Electric Vehicle (EV) sales because EVs do not emit CO_2 while driving. However, EVs have some characteristics that conventional vehicle does not have. For example, EVs have a short driving distance comparing with gasoline vehicles, and it takes time to charge the battery on the outside charging spot, and the spread of the charging spot is limited. And since EVs use the motor for driving, EVs can charge the own battery by using regeneration. We have been constructed the EV driving support system by using Geographic Information System (GIS) for supporting users of EV that has such characteristics. And we use road network data and the Digital Elevation Model (DEM) and EV driving data on GIS. In this research, we focus on the influence of personal driving characteristics for the EV power consumption, and we constructed the EV driving support system considering the personal driving characteristics.

Keywords: Geographic information system, electric vehicle, navigation system, digital elevation model

1. Introduction

In recent years, environmental issues such as global warming are progressing all over the world with economic development. And one of the causes is the increase of greenhouse gas such as carbon dioxide, methane gas, and nitrous oxide. Especially, the total amount of CO_2 emission is greatly increasing. The worldwide emission of CO_2 is 14.6 billion tons in 1971, but the total amount becomes over twice as 32.9 billion tons in 2015 [1]. The amount of CO_2 emission from the transport sector accounts for 23% of the total amount of CO_2 emission, and it is the second-largest ratio next to electricity and heat [2]. Therefore, we can know the automobile emits a large amount of CO_2. Thus, one of the big causes of global warming is CO_2 emission from automobiles, and it is required for motor companies to reduce CO_2 emission from automobiles.

From these facts, motor companies have been started to sell new energy vehicles, and some preferential policies for these automobiles are adopted in some countries and regions. For example, Germany aims to ban the sales of combustion vehicles by 2030, and Netherland also aims to ban the sales of combustion vehicles by 2025[3].

Therefore, EVs are spreading rapidly because it does not emit CO_2 while driving, and it does not use fossil fuels. However, EV has problems such as shorter cruising range than combustion vehicles due to the limited capacity of the built-in storage battery, and it takes a long time to charge the battery, and the charging spot is not so widespread. Moreover, since EVs use a motor as a power source, they have characteristics that internal combustion engine vehicles do not have, such as the presence of regenerative

* Manuscript received September 21, 2020; revised March 30, 2021.
Corresponding author. *E-mail address*: nakayama.shuntaro817@mail.kyutech.jp.
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brakes and different power consumption depending on the traveling speed (e.g., when traveling on a highway or with traffic jams)[4][5]. To solve these problems, it is required for EV users that the system manage EV power consumption and to support EV users. And EVs have special characteristics. Therefore, EV users look for the car navigation system carefully considering the characteristics of EV. However, the current EV navigation system does not meet the requirements.

Therefore, we have been constructed the system to support EV users by using GIS, road network, DEM, and charging spots information, where sets of EV driving data are managed on GIS. This system can provide estimated power consumption from departure point to destination for EV users.

We have to consider the influence of personal driving characteristics for accurate EV driving power consumption estimation. From previous studies, we have constructed the standardization method for the calculation of estimated power consumption formula [6] which is used for estimating the EV driving power consumption. In this study, we have revealed the differences in personal driving characteristics and corrected the formula according to the personal driving data by using the previous method [6]. As a result, the developed EV driving support system reflects the personal characteristics to estimate power consumption matching the actual driving characteristics of each user.

2. GIS Utilization Overview and EV Power Consumption Estimation Formula

2.1. GIS utilization overview

GIS stands for Geographic Information System, and it is a technology for modeling the real-world infrastructure on a computer. GIS can deal with several data based on Geographic Information and GIS can perform several analyses by using these data. GIS uses layer data (e.g., road network data, elevation data) for modeling the real world. GIS can deal with several data at once, and it is possible to support the decision of the user. The primary functions of GIS used in this research are 1) the management of data by positioning information and attributing information, and 2) the map expression by overlaying layers [7]. The overview of the main functions and data of GIS is shown in Fig. 1. Therefore, it is possible to construct of EV driving support system by analyzing several data (e.g., road network, DEM, EV driving data, distribution of charging spot) on GIS.

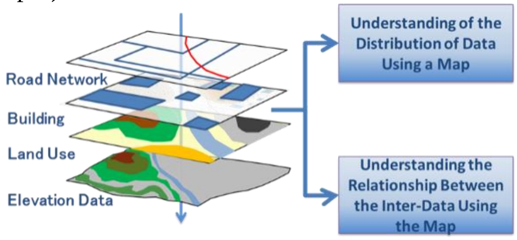

Fig. 1. The basic principle of GIS formula

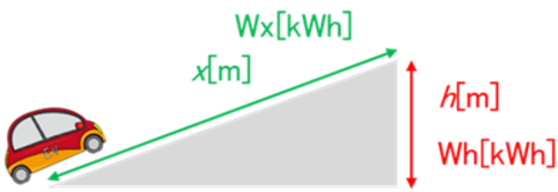

Fig. 2. Outline of the power consumption estimation

2.2. EV power consumption estimation formula

We had proposed the EV driving power consumption estimation formula for estimating the driving power consumption. EVs use the motor for driving. Therefore, this formula has to consider the influence of regeneration. The outline of the power consumption estimation formula is shown in Fig.2. We divide power consumption into the horizontal component and the vertical component. From this, the estimation formula can consider the influence of slope. [8]

$$W = x/a + W(h) \tag{1}$$

Formula 1. shows the EV power consumption estimation formula. In this formula, a means electricity expense[km/kWh] and x means distance[km]. The term bh means vertical power consumption, and b means vertical electricity expense[kWh/km], and h means the difference of elevation. The term ct means the power consumption of the air conditioner, and c means the power consumption coefficient of the air conditioner and t means the air conditioner usage time [9]. Coefficient x and h can be obtained from the road network, and DEM on GIS and t is also can be calculated by using distance and regal speed information on the road network. These coefficients are calculated from EV driving data.

3. EV Driving Support System Considering the Personal Driving Characteristics.

3.1. Influence of the personal driving characteristic

Assuming the actual usage of the EV, it will be used by multiple people. However, the system that displays the cruising range installed in EVs displays the cruising range for each car, and the influence of personal driving characteristics cannot be taken into consideration. Internal combustion engine vehicles also display fuel efficiency, but it is the average fuel efficiency of all the people use the car. Therefore, the influence of personal differences also cannot be taken into consideration. In this research, it is assumed that the driver will be managed with an ID card, and the data will be acquired for each driver.

Table 1. Power consumption

Driver	Power consumption [kWh]
A	2.97
B	3.50
C	4.42

Fig. 3. Driving data

We compared the EV driving power consumption of three people by the route shown in Figure3. In this study, we did not consider the influence of the air conditioner because it is not depending on the personal driving characteristics. Table1 shows the power consumption varies greatly among personals, even though they drive on the same route. Especially, the power consumption of driver A and C is about 1.5 times different. From this result, there is a great difference in personal driving characteristics. Therefore, EV users require the EV power consumption estimation system considering that influence.
Correction of power consumption estimation formula

3.2. Correction of power consumption estimation formula

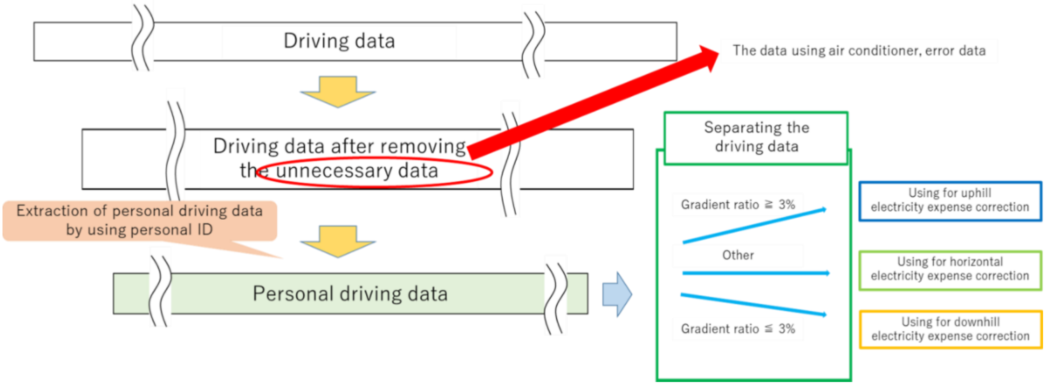

Fig. 4. The method of correction for EV power consumption estimation formula

We corrected the EV driving power consumption estimation formula by using the method shown in Fig. 4. The method of correction is based on the previous study [6]. Formula (2) and (3) shows the calculation method. a_{ini} and b_{ini} show the base electricity expense and a_n and b_n are calculated every minute by the method shown in Fig.4. Therefore, we could obtain a_{new} and b every minute.

$$a_{new} = \frac{a_{ini}+\sum_{n=1}^{N} a_n}{n+1} \tag{2}$$

$$b_{new} = \frac{b_{ini}+\sum_{n=1}^{N} b_n}{n+1} \tag{3}$$

Table 2. Comparison of electricity expense

Driver	Horizontal electricity expense [kWh/km]	Uphill electricity expense [kWh/m]	Downhill electricity expense [kWh/m]
A	0.1167	0.00111	0.00048
B	0.1166	0.00137	0.00081
C	0.1217	0.00108	0.00078
D	0.1161	0.00161	0.00130
E	0.1341	0.00191	0.00094
F	0.1237	0.00184	0.00060
G	0.1073	0.00135	0.00068

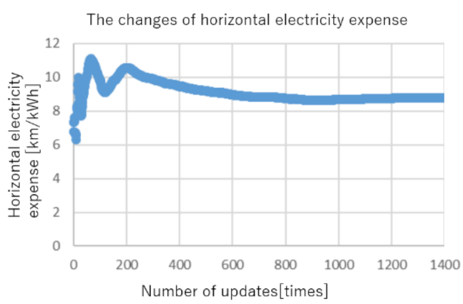

Fig. 5. Convergence status of horizontal electricity expense

Fig. 5 shows the transition of horizontal electricity expense when this method is applied. From this result, the values vary when the few amounts of driving data, but the values converge when the driving data is accumulated. By accumulating the traveling data in this way, it is possible to grasp the tendency of the personal electricity expense. However, the driver gradually becomes accustomed to driving, and the electricity expenses change over the long term. Therefore, it needs to be constantly updated.

Table 2 shows the personal electricity expenses by using the above method, and these data are converged data. From this result, these electricity expenses are different depending on the personal and especially, there are 0.0268[km/kWh] differences of horizontal electricity expenses between the driver E and the driver G. In the case of the LEAF 40kWh model, it shows that the cruising range is 74.6km different by using their electricity expenses, and the influence of personal driving characteristics is large.

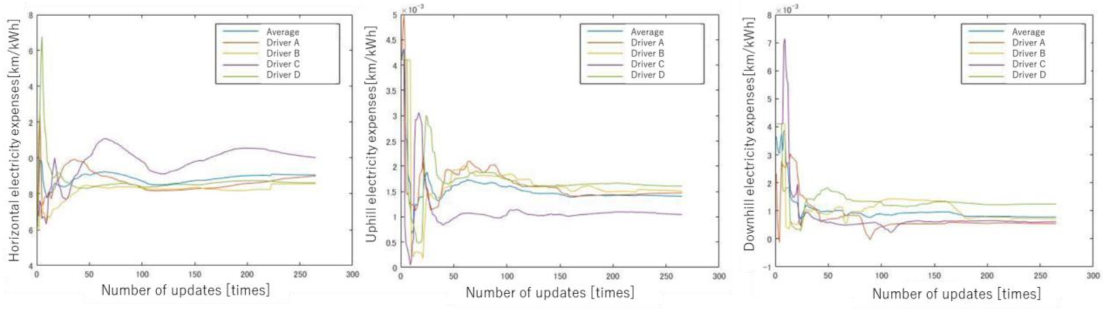

Fig. 6. Comparison of electricity expense

Fig. 6 shows the comparison of the personal electricity expenses by using this method. From this figure, these electricity expenses tend to depend on the characteristic of personal driving. Moreover, it is also possible to evaluate the user driving by comparing the average electricity expense of all users and the personal electricity expense by using this system.

3.3. Power consumption estimation considering the personal driving characteristics

By using this result, we constructed the EV driving power consumption estimation system on GIS. It is possible to estimate the power consumption from departure point to destination by using this system. We used this system to express personal driving characteristics. We also used Worldwide-harmonized Light vehicles Test Cycle (WLTC) electricity expenses (0.155[kWh/km]) for estimation [10]. We used the two routes for comparison of power consumption of each driver and the route 2 includes the highway.

Table 3. Comparison of power consumption (route 1)

Driver	Estimated value (WLTC)	Estimated value (this system)
A	7.25[kWh]	5.07[kWh]
B	7.25[kWh]	5.49[kWh]
C	7.25[kWh]	6.00[kWh]

Table 4. Comparison of power consumption (route 2; includes the highway)

Driver	Estimated value (WLTC)	Estimated value (this system)
A	25.57[kWh]	22.00[kWh]
B	25.57[kWh]	28.21[kWh]

These results are shown in Table 3 and Table 4. By comparing the estimation value of each user, there is an obvious difference. And the estimation value using WLTC can’t express the influences of personal driving characteristics. From this result, it is clear that the estimated values are different depending on the driver, even if they drive the same route. Therefore, this system can provide whether EV users can travel to their destination with the current battery level with consideration of personal driving characteristics.

4. Conclusion

In this research, we have constructed the EV driving support system that considers the influence of personals. The current car navigation system cannot manage the driving data for each person. However, the characteristic of driving is completely different on each driver. Therefore, it is required for EV users that the driving support system considering the influence of the personal. To construct this system, we investigated the influence of driving characteristics for electricity expenses and corrected the power consumption estimation formula for each driver. By using this formula, we constructed the EV driving support system on GIS, and we could construct a system that provides the estimated power consumption for each driver. In the future, we will build a system that responds to sudden changes in driving characteristics and changes in road conditions and evaluates driving and estimates power consumption.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

All authors conducted the research; Shuntaro Nakayama analyzed data and wrote the paper; All authors had approved the final version.

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