Estimation of Fuel Consumption using In-Vehicle Parameters

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Abstract

This Paper proposed the estimation method of fuel consumption from vehicle information through OBD-II. We assumed RPM, TPS had a relationship with fuel consumption. We got the output as fuel-consumption from a vehicle RPM, TPS as input by using polynomial equations. We had modeling as quadric function and surface function with OBD-II data and fuel consumption data supported by automotive company in real. In order to verify the effectiveness of proposed method, 5 km road-test was performed. The results showed that the proposed method can estimate precisely the fuel consumption from vehicle multi-data. It was observed that the proposed models using instantaneous engine RPM, TPS and (RPM, TPS) can predict the fuel consumption quite well with the coefficient of determination were 76%, 88% and 71% respectively.

Keywords: *Fuel consumption, On Board Diagnosis, RPM, TPS, Polynomial equation.*

1. Introduction

Vehicle fuel consumption and emissions are two critical aspects considered in the transportation industry. In order to become energy independence and reduce greenhouse gas (GHG) emissions from transportation sector, policy makers are pushing for more efficient vehicles, the use of alternative, low carbon fuels, and the adoption of sustainable community strategies. Eco-driving is one of the conservation programs that can be very cost effective. At the central part of many eco-driving programs, a variety of advice is provided to drivers to minimize fuel consumption while driving. Specific advice include items such as shifting to a higher gear as soon as possible, maintaining steady speeds, anticipating traffic flow, accelerating and decelerating smoothly, keeping the vehicle in good maintenance, etc. Different eco-driving programs have been found to yield fuel economy improvements on the order of 5 to 15%. Most eco-driving research to date has been concentrated on providing eco-driving advice to drivers, and then measuring before and after differences. Alternatively, it is possible to provide various forms of eco-driving feedback to drivers.

It is necessary to announce the current fuel consumption to driver. However, most motor companies are unwilling to reveal the vehicle information. Therefore, easily obtained diagnostic information can be used to estimate the fuel consumption roughly.

Current state-of-the-art models estimate vehicle consumptions based on typical urban driving cycles. Most of these models offer simplified mathematical expressions to compute fuel and emission rates based on average link speeds [1-3].

In this paper develops mathematical models that predict vehicle fuel consumption using instantaneous engine RPM and TPS (Throttle Position Sensor) through OBD-II (On Board Diagnosis). The result of this experiment shows the possibilities of fuel consumption modeling.

2. OBD-II System

On-Board Diagnostic systems are in most cars and light trucks on today. During the 1970s and early 1980s manufacturers started using electronic means to control engine functions and diagnose engine problems. This was primarily to meet EPA (Environmental Protection Agency) emission standards. Through the years on-board diagnostic systems have become more sophisticated. OBD-II, a new standard introduced in the 1990s, provides almost complete engine control and also monitors parts of the chassis, body and accessory devices, as well as the diagnostic control network of the car.

To combat its smog problem in the LA basin, the State of California started requiring emission control systems on 1966 model cars. The federal government extended these controls nationwide in 1968. Congress passed the Clean Air Act in 1970 and established the Environmental Protection Agency (EPA). This started a series of graduated emission standards and requirements for maintenance of vehicles for extended periods of time. To meet these standards, manufacturers turned to electronically controlled fuel feed and ignition systems. Sensors measured engine performance and adjusted the systems to provide minimum pollution. These sensors were also accessed to provide early diagnostic assistance.

At first there were few standards and each manufacturer had their own systems and signals. In 1988, the Society of Automotive Engineers (SAE) set a standard connector plug and set of diagnostic test signals. The EPA adapted most of their standards from the SAE on-board diagnostic programs and recommendations. OBD-II is an expanded set of standards and practices developed by SAE and adopted by the EPA and CARB (California Air Resources Board) for implementation by January 1, 1996.

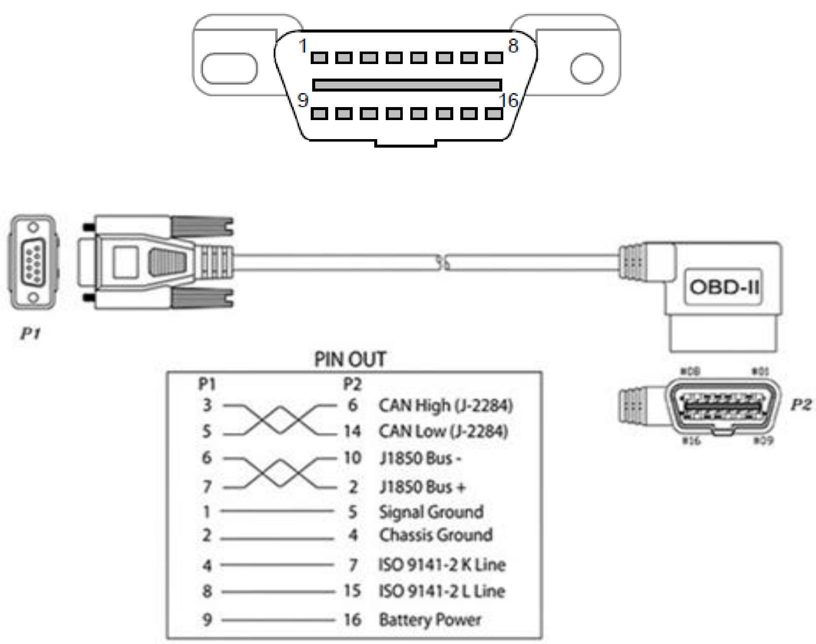


Fig. 1. OBD-II Port with Pin Layout

There are five basic OBD-II protocols in use, each with minor variations on the communication pattern between the on-board diagnostic computer and the scanner console or tool. While there have been some manufacturer changes between protocols in the past few years, as a rule of thumb, Chrysler products and all European and most Asian imports use ISO 9141 circuitry or KWP2000. GM cars and light trucks use SAE J1850 VPW (Variable Pulse Width Modulation), and Fords use SAE J1850 PWM (Pulse Width Modulation) communication patterns [4].

CAN is the newest protocol added to the OBD-II specification, and it is mandated for all 2008 and newer model years.

All cars built since January 1 1996, have OBD-II systems. Manufacturers started incorporating OBD-II in various models as early as 1994. Some early OBD-II cars were not 100% compliant.

The OBD-II standard specifies the type of diagnostic connector and its pinout, the electrical signaling protocols available, and the messaging format. It also provides a candidate list of vehicle parameters to monitor along with how to encode the data for each.

Figure 1 is a schematic of the OBD-II connector port located in vehicles.

OBD-II data port is located near the driver, usually under the dashboard as shown in Figure 2.

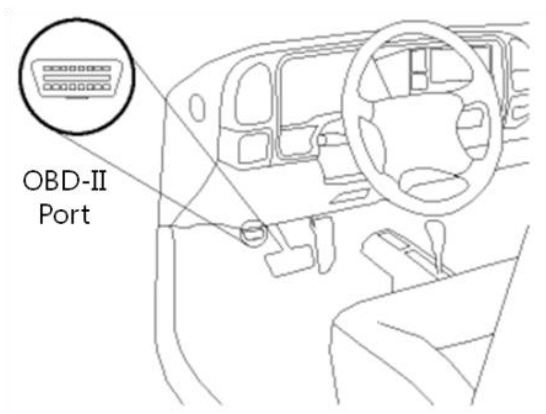


Fig. 2. OBD-II Port Locates under the Dashboard

OBD-II provides access to numerous data from the engine control unit (ECU) and offers a valuable source of information when troubleshooting problems inside a vehicle. The SAE J1979 standard defines a method for requesting various diagnostic data and a list of standard parameters that might be available from the ECU.

There are ten modes of operation described in the latest OBD-II standard SAE J1979. They are as follows (the 0x prefix indicates a hexadecimal radix) in Table 1. Vehicle manufactures are not required to support all modes.

Table 1. OBD-II Modes

Mode	Description
0x01	Show current data
0x02	Show freeze frame data
0x03	Show stored Diagnostic Trouble Codes
0x04	Clear Diagnostic Trouble Codes and stored values
0x05	Test results, oxygen sensor monitoring
0x06	Test results, other component/system monitoring
0x07	Show pending Diagnostic Trouble Codes
0x08	Control operation of on-board component/system
0x09	Request vehicle information
0x0A	Permanent DTC's (Cleared DTC's)

The various parameters that are available are addressed by "parameter identification numbers" or PIDs which are defined in J1979. For a list of basic PIDs, their definitions, and the formula to convert raw OBD-II output to meaningful diagnostic units.

OBD-II PIDs are codes used to request data from a vehicle, used as a diagnostic tool. These codes are part of SAE standard J/1979, are implemented in most cars sold in Korea since 2006. All cars sold in the United States are required to use the ISO 15765-4 signaling a variant of the Controller Area Network (CAN) bus.

The Table 2 shows the example of OBD-II PIDs as defined by SAE J1979. The expected response for each PID is given, along with information on how to translate the response into meaningful data [5].

Table 2. Example of OBD-II PIDs.

Mode (hex)	PID (hex)	Data (bytes)	Description	Units	Formula
01	06	1	Short term fuel trim—Bank 1	%	(A-128)*100/128
01	07	1	Long term fuel trim—Bank 1	%	(A-128)*100/128
01	08	1	Short term fuel trim—Bank 2	%	(A-128)*100/128
01	09	1	Long term fuel trim—Bank 2	%	(A-128)*100/128
01	0B	1	Intake manifold pressure	kPa	A
01	0C	2	Engine RPM	rpm	((A*256)+B)/4
01	0D	1	Vehicle speed	km/h	A
01	0F	1	Intake air temperature	°C	A-40
01	10	2	MAF air flow rate	g/s	((A*256)+B)/4
01	11	1	Throttle position	%	A*100/255

3. Experiments

After research on available OBD-II scanners on the automotive market, the OBDLink scan tool was chosen. The OBDLink supports all OBD-II compliant vehicles, and is compatible with all diagnostic software written for the ELM327-based interfaces. The ELM327 is designed to act as a bridge between OBD-II port and a standard RS-232 interface [6-7].

The test vehicle is Grandeur TG Q270 manufactured by Hyundai Motor Company. The Grandeur TG Q270 is full size sedan introduced for model year 2009. The fuel type is petrol and the transmission type is automatic [8].

Figure 3 is the experimental setup in the test vehicle.

Fig. 3. Experimental Setup

Figure 4 is 5 km driving route through urban areas. The laptop runs software developed in Visual C++ for this paper which manages the communication with the OBDLink device.

While driving on the route, we stored vehicle speed, engine RPM, TPS, and other parameters in the Table 2 using test program as shown in Figure 5.

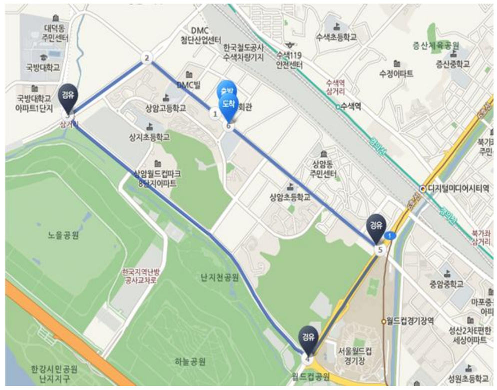


Fig. 4. Driving Route

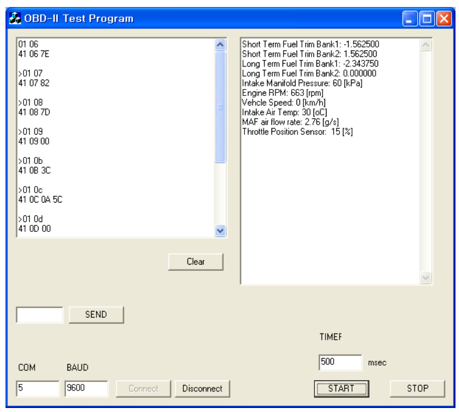
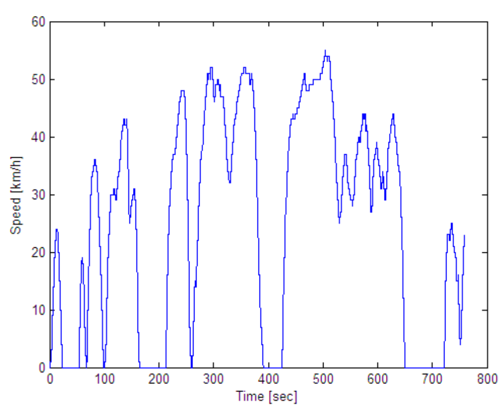
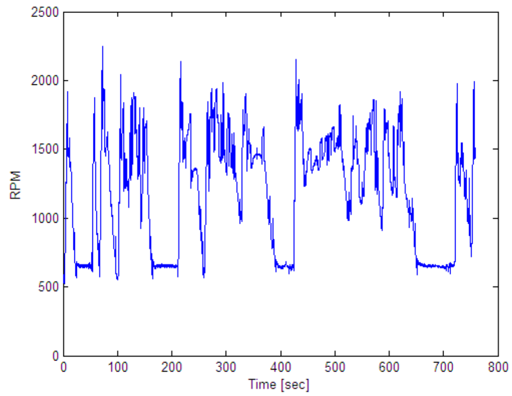


Fig. 5. Screenshot of the Test Program

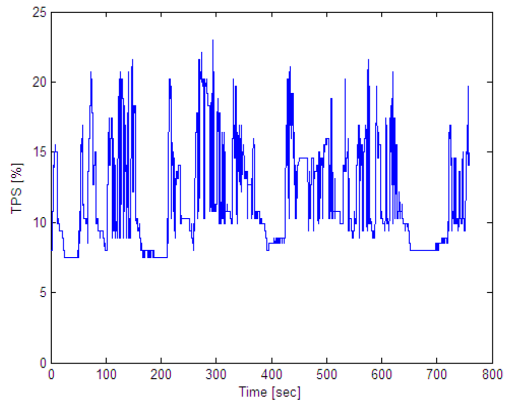
Figure 6 shows results of a measured real-world driving data from OBD-II.



(a)



(b)



(c)

Fig. 6. Measurement Data. (a) Vehicle Speed, (b) Engine RPM, (c) TPS

The fuel consumption data is supported by automotive company in real amount of fuel injection. This data has been used as a reference value to obtain an estimation model.

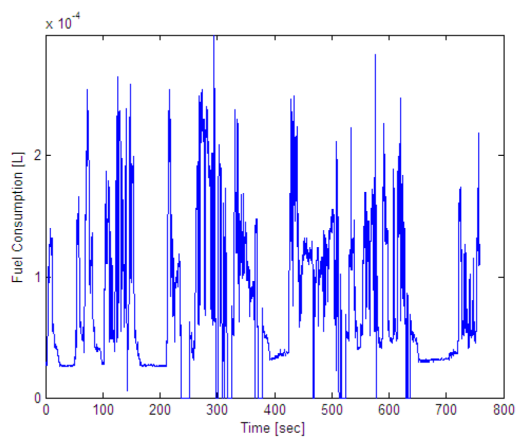


Fig. 7. Fuel Injection Data from ECU.

4. Data Analysis

Curve fit techniques are typically used where the underlying relations are generally known but too complicated to model in detail and the function is easily measured. These types of curves are generally considered to be empirical models. Statistical data regressions are performed to fit the measured data to mathematical equations.

Figure 8 illustrates a scatter plot of the relationship of fuel consumption vs. RPM, and Figure 9 is relationship of fuel consumption vs. TPS. The data is fitted to a linear and quadratic polynomial using a least square method.

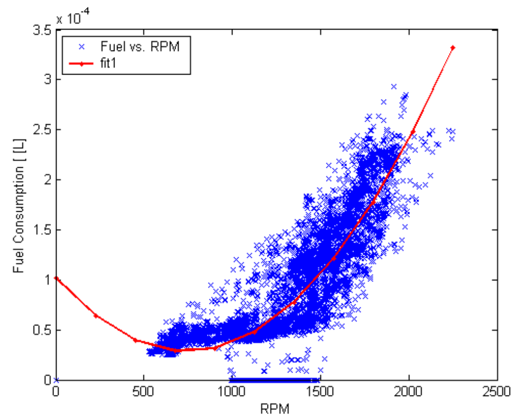


Fig. 8. Fuel Consumption vs. RPM

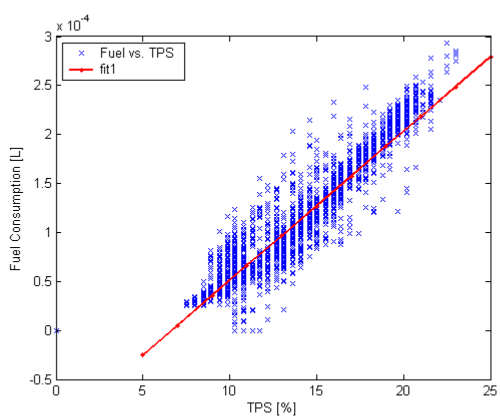


Fig. 9. Fuel Consumption vs. TPS

The positive relationships were found between engine RPM, TPS, and fuel consumption. Each curve was fitted using a Matlab program (curve fitting toolbox) to obtain regression functions.

The RPM and TPS regression functions can be expressed quadratic and linear models as shown in (1) and (2).

$$FUEL_{RPM} = ax^2 + bx + c, \quad (1)$$

$$FUEL_{TPS} = dx + e. \quad (2)$$

Where, a = 1.337e^{-10}, b = -1.986e^{-7}, c = 1.021×e^{-4}, d = 1.522e^{-5} and e = -1.013e^{-4}.

The $FUEL_{RPM}$ and $FUEL_{TPS}$ models produced determination coefficient R^2s are 76% and 88% respectively.

Figure 10 is surface fitting of fuel consumption with RPM and TPS.

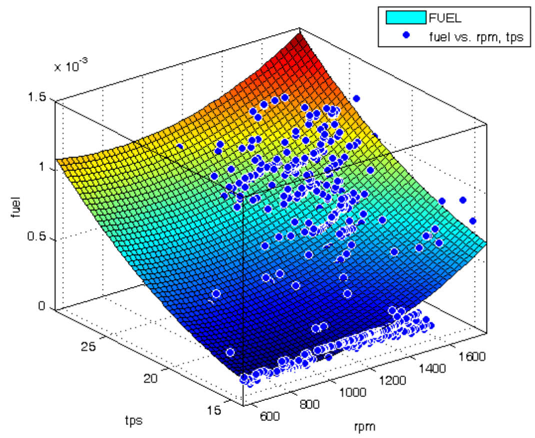


Fig. 10. Fuel Consumption vs. (RPM, TPS).

The surface regression function can be expressed linear polynomial model as shown in (3).

$$FUEL_{Poly22} = p00 + p10x + p01y + p20x^2 + p11xy + p02y^2, \qquad (3)$$

Where x and y are input variables, RPM and TPS, $p00$ = 1.5248e^{-4}, $p10$ = -1.9195e^{-7}, $p01$ = -1.0673e^{-5}, $p20$ = 1.2693e^{-10}, $p11$ = -9.6700e^{-10}, and $p02$ = 6.0900e^{-7}.

The coefficient of determination of the surface model is 71%.

Figure 11 is comparison results obtained by RPM and TPS fuel consumption models. These results show the predictive capability of proposed method using RPM, TPS.

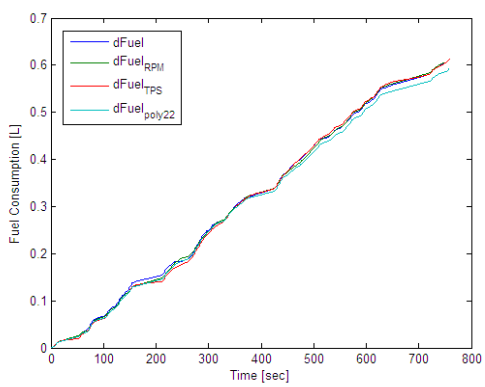


Fig. 11. Comparison Results

5. Conclusion

A methodology has been developed and demonstrated for estimation of fuel consumption that is based on recording engine RPM and TPS of vehicle's OBD-II data. These data are used to characterize the consumption of gasoline fuel. The fuel consumption varies highly with the model variables engine RPM and TPS. We had modeling as quadric function with OBD-II data and fuel injection data. The results showed that the proposed method can estimate the fuel consumption.

For the fuel consumption, there exists much more extensive data material from long-term follow-up of fuel consumption in the vehicles. An analysis of these data will give a better figure for the actual effects of eco-driving on fuel consumption.

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