

DRIVER DRIVING BEHAVIOUR PROFILING USING MACHINE LEARNING TECHNIQUES

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DECLARATION

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Date: 07:09:2016

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To my parents, my supervisors, and my friends.

ABSTRACT

This project proposed a driver driving behavior profiling method based on the on board diagnostic (OBD) information and K Means Algorithm. The proposed method collects the vehicle operation data and GPS data. The vehicle operation data includes include the vehicle speed, engine speed, engine coolant temperature, throttle position, acceleration sensor, GPS time, device time, latitude coordinate, longitude coordinate, GPS speed, GPS altitude, horizontal dilution of precision, GPS bearing, and GPS acceleration. The method makes use of the OBD interface, smartphone GPS device and Torque(Lite) Android application to do the data collection. A feature will be added on to the dataset. The value of the feature determines whether current vehicle speed exceeded the speed limit of the road or not. K Means algorithm will group the records into three clusters. Each record will be labeled as good, medium or bad condition data according to the cluster. Based on the number of each condition data the driver had, the driver can be profiled as low risk, medium risk or high risk driver.

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CHAPTER 1

INTRODUCTION

1.1 Basic Introduction

Currently, the amount of vehicles on the road increases every year in Malaysia. It is because the local brand car is affordable by many low-income level household. The manufacturer also provided promotions to attract people to buy car. So that, the number of non-professional driver rapidly increased in Malaysia. Most of the drivers are unskilled and lack of awareness on the traffic safety and vehicle condition. The driver's personal factors have become the main reason of causing the traffic incidents.

According to the general road accident data in Malaysia took from Malaysian Institute of Road Safety Research (MIROS) official website shown in Figure 1.1, the Malaysia government put effort on reducing the amount of traffic incidents by introducing the new traffic laws and speed track system. However, the number of cases of road deaths does not drop significantly.

General Road Accident Data in Malaysia (1997 – 2014)										
Year	Registered Vehicles	Population	Road Crashes	Road Deaths	Serious Injury	Slight Injury	Index per 10,000 Vehicles	Index per 100,000 Population	Index per billion VKT	
1997	8,550,469	21,665,600	215,632	6,302	14,105	36,167	7.37	29.1	33.57	
1998	9,141,357	22,179,500	211,037	5,740	12,068	37,896	6.28	25.8	28.75	
1999	9,929,951	22,711,900	223,166	5,794	10,366	36,777	5.83	25.5	26.79	
2000	10,598,804	23,263,600	250,429	6,035	9,790	34,375	5.69	26.0	26.25	
2001	11,302,545	23,795,300	265,175	5,849	8,680	35,944	5.17	25.1	23.93	
2002	12,068,144	24,526,500	279,711	5,891	8,425	35,236	4.9	25.3	22.71	
2003	12,819,248	25,048,300	298,653	6,286	9,040	37,415	4.9	25.1	22.77	
2004	13,828,889	25,580,000	326,815	6,228	9,218	38,645	4.52	24.3	21.1	
2005	15,026,660	26,130,000	328,264	6,200	9,395	31,417	4.18	23.7	19.58	
2006	15,790,732	26,640,000	341,252	6,287	9,253	19,885	3.98	23.6	18.69	
2007	16,813,943	27,170,000	363,319	6,282	9,273	18,444	3.74	23.1	17.6	
2008	17,971,901	27,730,000	373,071	6,527	8,868	16,879	3.63	23.5	17.65	
2009	19,016,782	28,310,000	397,330	6,745	8,849	15,823	3.55	23.8	17.27	
2010	20,188,565	28,910,000	414,421	6,872	7,781	13,616	3.4	23.8	16.21	
2011	21,401,269	29,000,000	449,040	6,877	6,328	12,365	3.21	23.7	14.68	
2012	22,702,221	29,300,000	482,423	6,917	5,868	11,654	3.05	23.6	13.35	
2013	23,819,256	29,947,600	477,204	6,915	4,597	8,388	2.90	23.1	12.19	
2014	25,101,192	30,300,000	476,196	6,674	4,432	8,598	2.66	22.0	10.64	

Figure 1.1: General Road Accident Data in Malaysia (1997 - 2014)

The driver characteristics and the occurrence of traffic incident is interrelated. To further reduce the number of accidents, the safety equipment of the vehicle need to

be improved as well as the road regulation, but also pay attention on driver behavior. The behavior of the driver is hard to be identified. The driver behavior is affected by environment, vehicle condition and the mental or physical state. One way to identify driver behavior is using the vehicle operation data.

1.2 Project Objective

1. To identify the features that contribute to the accuracy of the classification of the driver behavior analysis from the vehicle operation data.
2. To classify each vehicle operation records.
3. To profile the drivers based on the labeled vehicle operation data.

1.3 Research Motivation

This project is designed to capture actual driving behavior data by using sensor. The driver behavior will be analyzed based on the vehicle operation data collected from the sensor plugged in the particular vehicle. This project will use the ELM327 as a device that communicates with the vehicle OBD-II interface. The GPS data and vehicle operation data will be collected through the application Torque(Lite) via Bluetooth. The performance index for approach and alienation will be used in this project as a feature to analyze the drivers' driving behavior. The driver who exceed the speed limit can be detected by using the vehicle speed and the GPS location information.

1.4 Project Scope

This project focuses on the driver behavior profiling. The vehicle operation data will be collected and preprocessed before execute the analysis. Each driver is required to drive the car at least 8 minutes for vehicle operation data collection. The data will be recorded in every second. For each driver, there are at least 480 records in the vehicle operation data file. After using the machine learning technique to classified

the drivers, the drivers will be categorized to three classes. The classes are low risk, medium risk and high risk.

1.5 Project Plan

Proper time and resource management is important to complete this project. Table ?? shows a brief description of the project timeline.

Task \ Week	2	3	4	5	6	7	8	9	10	11	12
Data Acquisition											
Literature Review											
Data Analysis using KNIME											
Driver Driving Behavior Profiling											
Analyzing Experimental Result											
Documentation and Report											
Report Submission											

Table 1.1: Project timeline of Final Year Project I for Trimester 1 2016/2017

CHAPTER 2

RELATED WORK

2.1 Introduction

Various literature have introduced driving behaviour analysis. Driving behavior can be influenced by the emotion of the drivers. The driver may drive faster when they felt angry or sad. Most of the accidents are caused by the distracted driver. The driver may be distracted by phone call while driving. Driver behavior is hard to be determined by the speech emotion of the driver.(Kamaruddin & Wahab, 2010)

The driving environment will also affect the driver behavior. Some of the driver will pass through the intersection without stopping and observing the surrounding condition. The decision of drivers for passing through certain road condition will reflect the drivers' driving behavior.

The vehicle operation data will direct reflect the driver driving behavior. Vehicle speed can determine the current driving state whether increasing speed or remaining safe. Engine speed can determine the efficiency of the vehicle operation. The number of fuel sent to the engine is determined by the throttle position. Suitable throttle position will ensure that the engine operates efficiently. Inappropriate throttle position will cause incomplete combustion of fuel and air pollution.(Chen, Pan, & Lu, 2015)

2.2 Driver Behavior Analysis through Speech Emotional Understanding

This paper was proposed by Kamaruddin and Wahab(2010). The researchers analyzed the driver behavior state (DBS) based on the emotion of the driver when the driver was driving. The emotion of the driver can be detected through speech. The scholars used the Berlin data set and NAW data set as training set. The Berlin data set and NAW data set are standard data set for speech emotion recognition and have been

used by many researchers. The proposed method used the Generic Self-organizing Fuzzy Neural Network (GensoFNN) as a classifier for identification purpose.

2.2.1 Generic Self-organizing Fuzzy Neural Network (GensoFNN)

Fuzzy neural network is the combination of neural network and fuzzy inference system. It contains the interpretability of fuzzy inference system and the adaptability of neural network. GensoFNN is a classifier that can generate consistent result as it is able to do self-clustering process of the training data.

2.2.2 Driver Behavior Analysis Method

This proposed method collected data from 11 adults (3 female and 8 male). The drivers have at least two years of driving experience and drive at least 10 hours per week. The drivers are required to do four designed actions. The actions are:

1. driver talking through the mobile phone while driving.
2. driver feeling sleepy.
3. driver laugh while driving
4. driver in the initial driving exercise where the driver is in neural state of emotion.

A microphone is embedded in the vehicle to collect the speech of the driver while driving. The experiments to analyzed the three DBS of talking, laughing, and sleepy were conducted. The researchers use the Berlin data set and NAW data set to relate the three DBS with the angry, happy, and sad emotion.

2.2.3 Conclusion

The result shows that the sleepy DBS can be recognized as sad emotion consistently. However, the talking and laughing DBS gave mixed results. It means that more work

need to be conducted for better classification of the two DBS. The accuracy of sleepy emotion detection is up to 65% using the proposed speech emotion recognition system.

2.3 Driver Behavior Analysis and Route Recognition by Hidden Markov Models

This paper was proposed by Sathyanarayana, Boyraz, and Hansen(2008). This paper introduced the driver behavior modeling using Hidden Markov Models (HMM) in Bottom-to-Top Approach and Top-to-Bottom Approach.

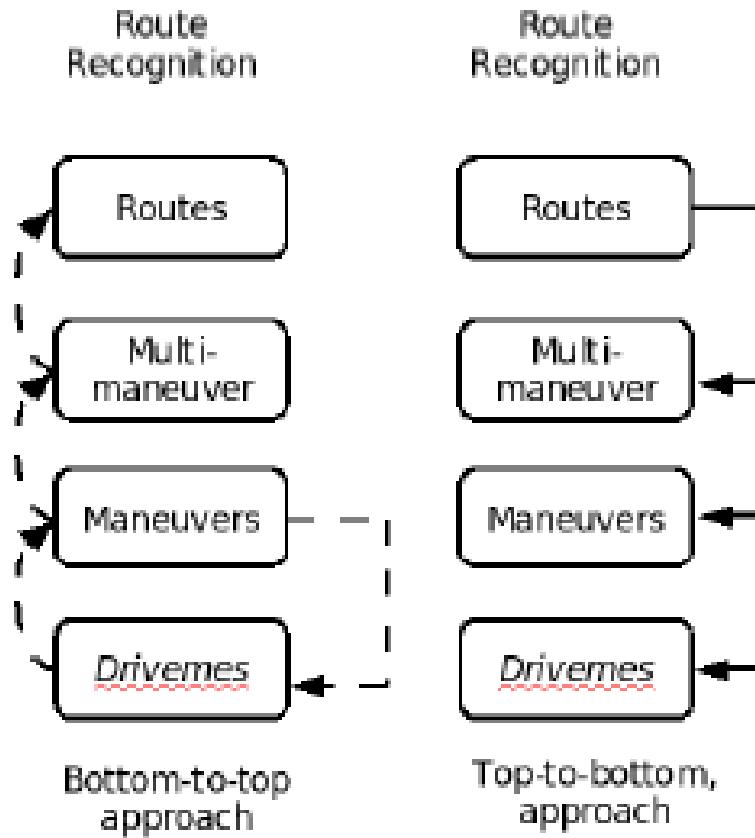


Figure 2.1: Hierarchy among the units of route recognition (Sathyanarayana et al., 2008)

In the Bottom-to-top approach, the maneuvers are the smallest unit to be recognized by the algorithms. The driver behavior can be discovered from the recognized maneuvers and be used to build the maneuver models. The multi-maneuver models use the maneuvers model to be built and finally become a complete route. The Bottom-to-Top approach is to detect the distraction of driver based on the comparison of the neutral

state vehicle operation data in the known maneuvers.

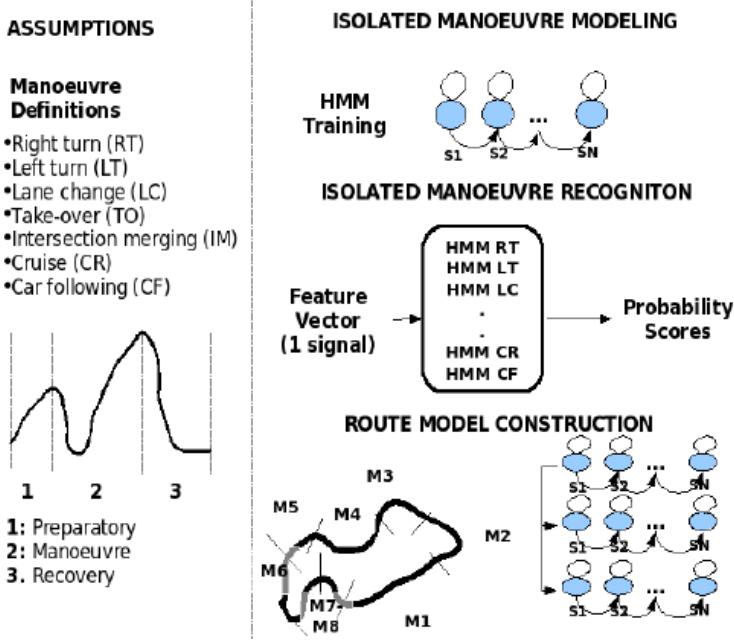


Figure 2.2: Bottom-to-top approach for route model construction (Sathyaranayana et al., 2008)

In Top-to-Bottom approach, it is an opposite approach in driving behavior modeling. A single HMM is used to parse the route to the individual meaningful parts like maneuvers and states. The result of this approach is that the driver behavior in intersection will be identified by using three main clusters. The Top-to-Bottom approach is to recognized the route based on the vehicle operation data.

2.3.1 Data Collection

The proposed method used UTDrive Vehicle to collect the data. The UTDrive Vehicle is converted from a Toyota RAV4 vehicle. The UTDrive Vehicle is equipped camera to capture the driver and the road. The driver speech also been recorded by the equipped microphone in the vehicle. Distance sensor using laser and GPS for position measurement are also equipped. The CAN-Bus is used to collected the vehicle speed, steering wheel angle, and brake/gas information. The vehicle also equipped gas/brake pedal pressure sensors.

The experiment conducted in two different areas in order to collect two different

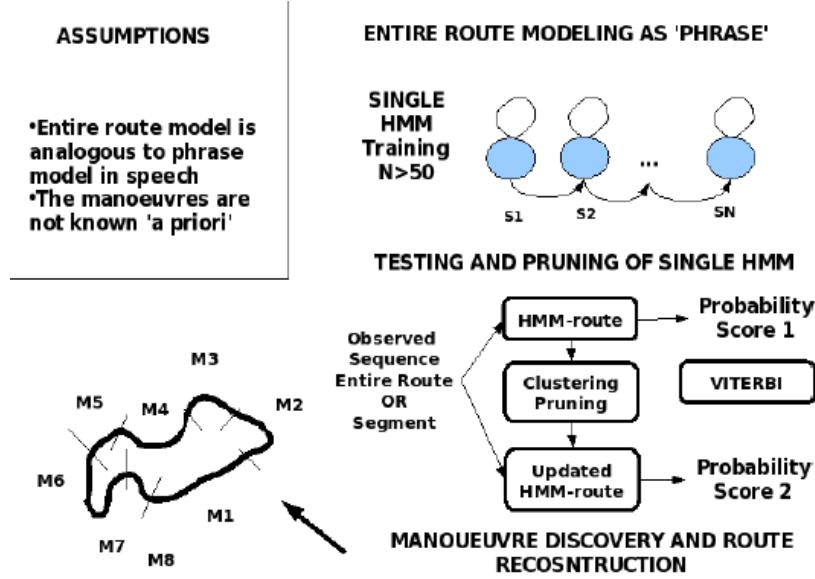


Figure 2.3: Top-to-bottom approach for route model construction (Sathyaranayana et al., 2008)

scenarios data. The residential and commercial area including the right turn, left turn and lane change were selected for drivers to drive through. The drivers were required to drive two times with neutral driving and distracted driving.

2.3.2 Conclusion

Three different types of maneuvers (left turn, right turn, and lane change) were recognized by using the three CAN-Bus signals (vehicle speed, steering angle, and brake force). On the other hand, the distraction detection was recognized and having 95% accuracy.

2.4 Driving Behavior Analysis Based on Vehicle OBD Information and AdaBoost Algorithms

This paper was proposed by Shi-Huang et al.(2015). The researchers analyzed the drivers' behavior based on the on board diagnostic (OBD) information and using the AdaBoost Algorithms to create the driving behavior classification. Finally, the experimental results show the correctness of the proposed driving behavior analysis method has 99.8% accuracy rate in various driving simulations.

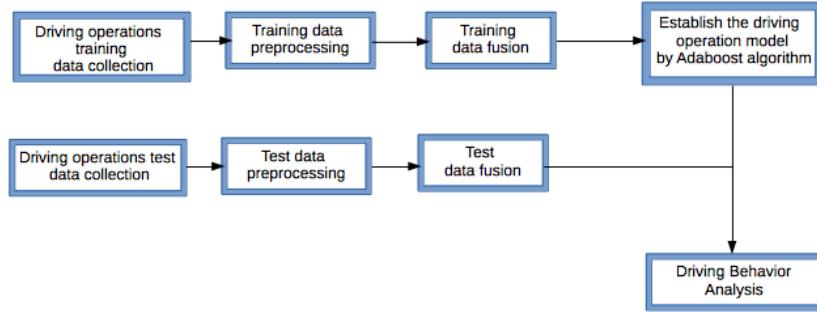


Figure 2.4: The flowchart of the proposed driving behavior analysis method.

2.4.1 AdaBoost Algorithms

AdaBoost is a classification machine learning algorithm. The AdaBoost algorithms is to form a strong classifier by combining the a large number of weak classifier. There are three different types of AdaBoost algorithms. They are Gentle AdaBoost, Modest AdaBoost and Real AdaBoost.

2.4.2 Driving Behavior Analysis Method

This proposed method used the OBD-II system in the vehicle and EZ-SCAN5 as the OBD-II to Bluetooth adapter to collect the vehicle operation information. OBD-II is proposed in 1996 to replace the OBD-I system. The OBD-II system is implemented in every vehicle under the Environmental Protection Agency (EPA) regulation in USA since 1996. When the air-pollution contents exhausted by the vehicle exceed the minimum level, the OBD-II system of the particular vehicle will generate the Diagnostic Trouble Code (DTC) message and Check Engine light will display on the vehicle dashboard. In order to communicate with the OBD-II system of the vehicle, EZ-SCAN5 as a OBD-II to Bluetooth adapter is required. The EZ-SCAN5 support most of the OBD-II communication protocols, such as SAE J1850 PWM, SAE J1850 VPW, ISO 9141-2, ISO 14230-4 KWP, and ISO 15765-4 CAN. If the communication protocol of the OBD-II system is not supported by the adapter, the vehicle operation information will not be able to retrieve.

This proposed method collected vehicle speed, engine speed(RPM), throttle position and engine load as the vehicle operation information. According to the engine characteristic curve, the proposed method developed two criteria for the data collection.

1. The normal vehicle condition data

The relative ratio of the vehicle speed and the engine speed is remained in a range that between 0.9 and 1.3. The result was tested in the same gear. The relative ratio of the engine speed and throttle valve is remained in a range that between 0.9 and 1.3. The engine load is remained between 20% and 50%.

2. The bad vehicle condition data

The relative ratio of the vehicle speed and the engine speed is out of the range that between 0.9 and 1.3. The result was tested in the same gear. The relative ratio of the engine speed and throttle valve is out of the range that between 0.9 and 1.3. The engine load is out of the range that between 20% and 50%.

2.4.3 Vehicle OBD information Data Preprocessing

The proposed method used three characteristics. The three characteristics are the relative ratio of the vehicle speed and engine speed, the relative ratio of throttle position and engine speed, and engine load. Using the characteristics to analyzed the current state of the driving behavior whether the driver is in safe state or dangerous state. The proposed method needed to compute the change rate of vehicle speed, engine speed and throttle position in the first step. The calculation shown in Equation(2.1), where $t_2 - t_1 = 1$.

$$D(t) = \frac{data(t_2) - data(t_1)}{t_2 - t_1} \quad (2.1)$$

The next step is to calculate the relative ratio of the vehicle speed and engine speed, and the relative ratio of the throttle position and engine speed. The calculation shown in the Equation(2.2) and (2.3).

$$R_{cz}(t) = \frac{cs(t)}{220} \div \frac{zs(t)}{8000} \quad (2.2)$$

where $R_{cz}(t)$ is the relative ratio of engine speed and vehicle speed. $cs(t)$ is the vehicle speed at time t . The 220 is the value of maximum vehicle speed. $zs(t)$ is the engine speed a time t . The 8000 is the value of maximum engine speed of the vehicle.

$$R_{jz}(t) = \frac{jq'(t)}{\max(jq')} \div \frac{zs'(t)}{\max(zs'(t))} \quad (2.3)$$

where $R_{jz}(t)$ is the relative ratio of engine speed and throttle position. The $jq'(t)$ is the change rate of the throttle position at time t . $zs'(t)$ is the change rate of the engine speed at time t . The $\max(jq'(t))$ and $\max(zs'(t))$ is the maximum value of the change rate of throttle position and engine speed, respectively.

Based on the two computed features and engine load, this three features were combined to determine the vehicle data is normal or bad driving behavior.

2.4.4 Experimental Results

The proposed method used the toolkit-GML-AdaBoost-matlab of MATLAB to execute data preprocessing and driving behavior modeling. The preprocessed data is tested on three different types of the AdaBoost algorithms. They are Gentle AdaBoost, Modest AdaBoost and Real AdaBoost. The Real AdaBoost are better than other AdaBoost algorithms with the highest accuracy rate, 99.8%.

CHAPTER 3

REQUIREMENT

3.1 Hardware Requirement Introduction

In this project, a smartphone is required. The smartphone must have Global Positioning System (GPS) and Bluetooth device. A OBD-II to Bluetooth adapter, ELM327 is required to use in data collection. The model of vehicle used to collect driver data should be year 2006 onward. Some of the brand can not be supported by the ELM327 due to the protocols mismatch. The ELM327 supports most of the vehicle model with year 2008 in Proton brand, Toyota brand, and Honda brand. However, the latest model of the vehicle may not be supported due to the protocols mismatch problem also.

3.1.1 Vehicle OBD system

The OBD system is also called OBD-II, was proposed in 1996. In 1996, all the cars manufactured in United State (US) were required to equip OBD-II and the cars without OBD-II prohibited to sell in US. The purpose to have OBD-II specifications is to diagnose engine problem. The specifications were being used by the Environment Protection Agency (EPA) and the state of California to meet the emission standards. Since 1996, all the cars in US are required to be equipped with OBD-II to establish the EPA regulation.

The usage of the OBD-II is important for detecting the vehicle exhaustion. If the vehicle is exhaust high level of air-pollution content, Diagnostic Trouble Codes (DTCs) will be generated by the OBD-II and a Check Engine Light will be displayed on vehicle dashboard. OBD-II will store this DTCs into the Engine Control Unit memory. An OBD-II scanning tool can access the ECU to retrieve the DTCs.

The OBD-II is usually installed under the vehicle dashboard and above the pedals. Figure 3.1 shows the OBD-II socket of Toyota Vios year 2007 model.



Figure 3.1: OBD-II socket of the Toyota Vios year 2007 model.

3.1.2 ELM327

Super Mini ELM327 Bluetooth OBD-II is an OBD-II scanning tool produced by ELM Electronics. It is a programmed micro-controller to communicate with the OBD-II port of the vehicle. The ELM327 supports most of OBD-II protocols. ELM327 also contains the Bluetooth adapter. The ELM327 needs to be plugged to the OBD-II port.

3.2 Software Requirement Introduction

In order to collect the vehicle operation data, Torque(Lite), an Android application needs to be installed in the smartphone. Vehicle operation data will be stored in smartphone with Comma Separated Values (CSV) file format. Google Drive will be utilized to store the CSV file as a cloud storage.

In order to add on the new features to the dataset, Google Sheet and LibreOffice are used for modifying the dataset.



Figure 3.2: Super Mini ELM327 Bluetooth OBD-II.

Google Earth are used for verify the road structure that drivers drove through. The Torque(Lite) can convert the CSV file to Keyhole Markup Language (KML) file.

LibreOffice are applied in this project to do the final modification of the data set. After the modification, the data set will be stored as CSV format file. KNIME Analytic Platform is used for clustering the collected vehicle operation data by performing K Means Algorithm. The result will be visualized by using Tableau.

3.2.1 Torque(Lite)

Torque Lite version is a free android application and it is able to be installed in smartphone from Google Play Store. The application will communicate with the ELM327 through the Bluetooth connection. The application will collect the data received from the ELM327 and save the data into a CSV file in the smartphone.

After vehicle ignition is on, ELM327 need to connect with the smartphone that operating Torque via Bluetooth. Once the smartphone connected with the adapter, Torque will choose the protocol that matches with the OBD-II system. After the matching successes, Torque will start to read the sensor information from the ECU. In order to collect the GPS data, smartphone's location service is required to be enabled at the same time. When the smartphone received GPS signal and connected with the adapter, there are four flashing icons at the top right of the main screen will stay solid with blue color. Figure 3.3 shows a screen-shot of the Torque(Lite).



Figure 3.3: Screen-shot of the Torque(Lite).

3.2.2 KNIME Analytic Platform

KNIME Analytic Platform is an open platform for data analysis. It is a perfect tool for data scientists. The version of KNIME Analytic Platform used in this project is version 3.2.0.

KNIME Analytic Platform contain 1000 modules ,hundreds of ready-to-run examples, a set of integrated tools, and a list of advance algorithms available. User can build a machine learning experiment by dragging and dropping the related modules into the project. User needs to link and configure the module before execution.

This project uses the module of the KNIME Analytic to complete the data preprocessing and driving behavior modeling. K Means algorithm module is used in this project to classify the driving behavior.

3.2.3 K Means Algorithm

K Means algorithm is a popular clustering algorithm. The algorithm is used for automatically grouping data into cohesive 'clusters'. Few points will be initialized by choosing the training examples randomly. The number of the points is determined by the number of clusters wanted to be generated. For example, in order to get three clusters as output, three points is required to be initialized in the first step. The points are called cluster centroids (Ng, 2016).

The second step of the algorithm is an inner loop for performing two functions. The functions are shown below:

1. Assign each training example to the closest cluster centroids.
2. Move the cluster centroids to the mean of the points assigned to it.

This looping will be ended when the new iterations do not make the cluster centroids moved.

3.2.4 Tableau

Tableau is an software that has powerful data visualization functions. The data can be expressed by using graphics or diagrams in an interactive way. The version of the Tableau used in this project is version 10.0.

CHAPTER 4

DESIGN

4.1 Introduction

In this project, the driving behavior analysis method contains driving operation data acquisition module, data preprocessing module, data fusion module and K Means algorithm module. The raw vehicle operation data will be preprocessed. Each driver's vehicle operation data will be concatenated into a single CSV file. The new CSV file will be categorized to three group by using K Means algorithm. Figure 4.1 shows the flowchart of the entire project.

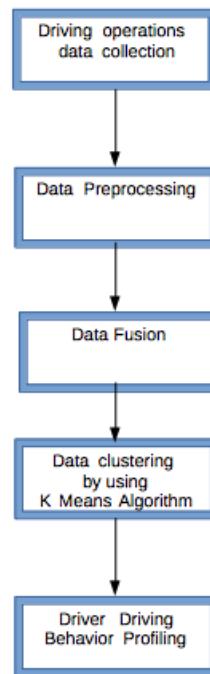


Figure 4.1: The flowchart of the driver driving behavior profiling method.

4.2 Driving Operation Data Acquisition

In this project, few drivers have been invited to participate in the data collection. The ELM327 device needs to be connected with the vehicle OBD-II socket. The

smartphone with the Torque(Lite) needs to be put in the vehicle. It needs to connect with the ELM327 device and GPS location service. Torque(Lite) logging function needs to be triggered and stopped in each driver driving session.

Vehicle operation data will be recorded in every second. The drivers are requested to drive at least 10 minutes. At least 600 vehicle operation records can be collected from each driver. All drivers was driving in different path. The raw data will be uploaded and stored in Google Drive. Figure 4.2 shows the view of the raw data in Google Drive.

	A	B	C	D	E	F	G	H	I	J	K	L
1	GPS Time	Device Time	Longitude	Latitude	GPS Speed (Meter/Sec)	Horizontal Dilution of Altitude	Bearing	G(x)	G(y)	G(z)	G(accelerated)	G(decelerated)
2	Fri Jul 29 18:46:16 C 7/29/2016 18:46:22	101.6402306	2.92723332	0	9	25	0	0.7059784	-0.64704895	0.921581	-0.05620438	
3	Fri Jul 29 18:46:17 C 7/29/2016 18:46:23	101.6402306	2.92723332	0	9	25	0	0.7648183	-0.33476257	0.139326	-0.04549464	
4	Fri Jul 29 18:46:18 C 7/29/2016 18:46:24	101.6402306	2.92723333	0	9	25	0	0.6668922	-0.3534988	0.91329	-0.05208055	
5	Fri Jul 29 18:46:19 C 7/29/2016 18:46:25	101.6402306	2.92723329	0	9	25	0	0.6863556	-0.4119873	0.844826	-0.05058828	
6	Fri Jul 29 18:46:20 C 7/29/2016 18:46:26	101.6402306	2.92723329	0	9	25	0	0.7451935	-0.37246704	0.838393	-0.06133418	
7	Fri Jul 29 18:46:21 C 7/29/2016 18:46:27	101.6402306	2.92723328	0	9	25	0	0.7940928	-0.3199197	0.878790	-0.05823897	
8	Fri Jul 29 18:46:22 C 7/29/2016 18:46:28	101.6402306	2.92723325	0	9	25	0	0.7732528	-0.3241154	0.817952	-0.05820579	
9	Fri Jul 29 18:46:23 C 7/29/2016 18:46:29	101.6402306	2.92723325	0	9	25	0	0.7732528	-0.3241154	0.817952	-0.05820579	
10	Fri Jul 29 18:46:24 C 7/29/2016 18:46:30	101.6402306	2.92723326	0	9	25	0	-0.2082020	0.5520984	0.022125	-0.05927329	
11	Fri Jul 29 18:46:25 C 7/29/2016 18:46:31	101.6402306	2.92723326	0	9	25	0	-0.2082020	0.5520984	0.022125	-0.05927329	
12	Fri Jul 29 18:46:26 C 7/29/2016 18:46:32	101.6402306	2.92723312	1.17126667	0	27	290.9	0.64846793	1.565842	0.711752	0.27398903	
13	Fri Jul 29 18:46:27 C 7/29/2016 18:46:33	101.6401183	2.92723366	2.214411	0	27	295.9	0.332021619	0.09828186	0.974829	-0.0502346	
14	Fri Jul 29 18:46:28 C 7/29/2016 18:46:34	101.6401128	2.92722241	5.34449462	0	29	267.5	0.1700369	-0.4661175	0.862346	0.038464211	
15	Fri Jul 29 18:46:29 C 7/29/2016 18:46:35	101.6401128	2.92721167	5.632877	0	28	298.8	0.28174927	-0.2098877	0.106842	-0.050941033	
16	Fri Jul 29 18:46:30 C 7/29/2016 18:46:36	101.6401158	2.92721167	6.79052628	0	25	270.3	0.17037964	-1.0087749	0.817206	-0.06608865	
17	Fri Jul 29 18:46:31 C 7/29/2016 18:46:37	101.6399661	2.92720804	5.720708	0	23	271.5	0.9607098	-1.6349573	0.277257	-0.015731871	
18	Fri Jul 29 18:46:32 C 7/29/2016 18:46:38	101.6399138	2.92720317	1.08008466	0	24	276.1	1.3730621	-1.0591125	0.812897	-0.05641598	
19	Fri Jul 29 18:46:33 C 7/29/2016 18:46:39	101.6398822	2.92719813	3.9636474	0	26	290.9	1.7655487	-1.078949	0.937970	-0.010585189	
20	Fri Jul 29 18:46:34 C 7/29/2016 18:46:40	101.6398512	2.92721568	3.5523794	0	23	309.8	1.7252592	-1.5488657	0.0678605	-0.027598033	
21	Fri Jul 29 18:46:35 C 7/29/2016 18:46:41	101.6398403	2.92723901	3.1892653	0	24	334	0.25497437	-0.16989	0.937152	-0.015921728	
22	Fri Jul 29 18:46:36 C 7/29/2016 18:46:42	101.6398348	2.92728428	2.810071	0	26	354.2	0.20907993	-0.50994873	0.823352	-0.1001696	
23	Fri Jul 29 18:46:37 C 7/29/2016 18:46:43	101.6398439	2.92727102	0.9536246	0	26	359.9	0.2827977	0.46427917	0.909166	-0.06111186	
24	Fri Jul 29 18:46:38 C 7/29/2016 18:46:44	101.6398407	2.92727884	0.46399654	0	25	359.7	0.6074047	-0.29447937	0.140198	-0.04878464	
25	Fri Jul 29 18:46:39 C 7/29/2016 18:46:45	101.6398459	2.92728969	0.20800614	0	25	359.8	0.41010032	-0.07359814	0.8767059	-0.06060629	
26	Fri Jul 29 18:46:40 C 7/29/2016 18:46:46	101.6398485	2.92728698	0.32140318	0	25	2.2	-0.01936403	-0.0393684	0.1203	-0.0510951	
27	Fri Jul 29 18:46:41 C 7/29/2016 18:46:47	101.6398497	2.92728455	0.75	0	24	10.1	0.35308838	0.25460815	8.843036	-0.21201701	
28	Fri Jul 29 18:46:42 C 7/29/2016 18:46:48	101.6398851	2.9272937	1.4022858	0	23	19.3	0.5100977	0.218813	0.7222816	-0.03908287	
29	Fri Jul 29 18:46:43 C 7/29/2016 18:46:49	101.639851	2.9272576	1.6211724	0	24	194.8	0.7651062	0.29441833	0.531921	-0.0057594776	

Figure 4.2: The raw data file is opened in Google Drive.

For this project, the vehicle OBD-II information data and GPS data need to be collected. The vehicle OBD-II information data include the vehicle speed, engine speed, engine coolant temperature, throttle position, and acceleration sensor. The GPS data include GPS time, device time, latitude coordinate, longitude coordinate, GPS speed, GPS altitude, horizontal dilution of precision, GPS bearing, and GPS acceleration. Those data will be written in a same file.

A new feature, speed test can be added into the data. Speed test is a value to determine whether the driver exceeded the speed limit or not at the particular time frame. The value of the speed test is '-1' or '1'. '-1' means the driver exceeded the speed limit at the particular time frame. '1' is on the contrast. The speed limit will be determined by the road condition. The road condition includes straight road,

curve road, traffic light intersection, intersection, roundabout, and state road. The road condition will be referred from the Google Earth. The KML file converted by the Torque(Lite) will show the path of the driver drove. In Figure 4.2, each record of the vehicle operation data will be displayed as a green arrow and marked on the map.

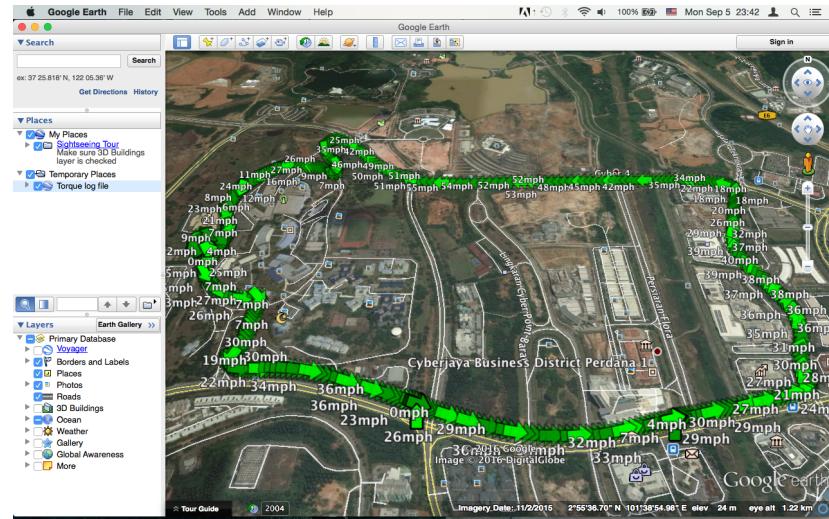


Figure 4.3: The Map View in Google Earth for the vehicle operation data.

In order to identify the intersection on straight road or differentiate the traffic light intersection and normal intersection, Google Earth provided the Street View function that allows to observe the surroundings of the particular place. In Figure 4.4, one of the traffic light intersection examples displayed in Google Earth.

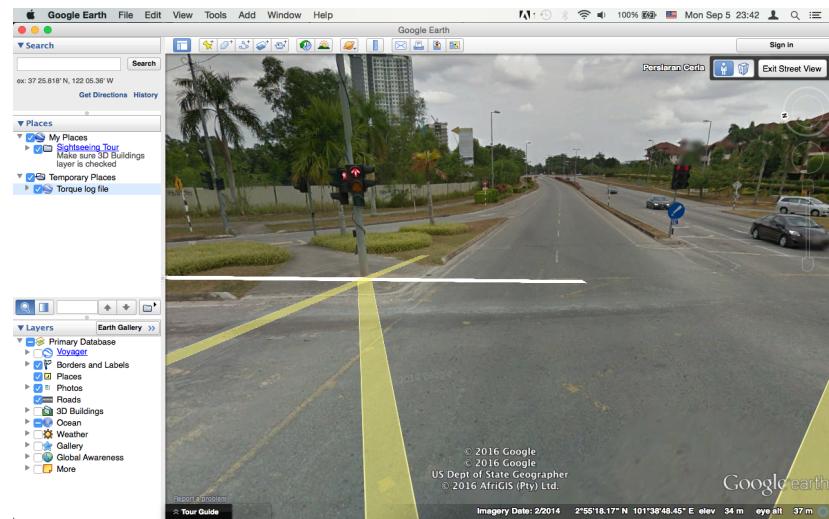


Figure 4.4: The Street View in Google Earth at the traffic light intersection.

In Malaysia, speed limit of expressways by default is 110 km/h, but it will be 90km/h in crosswind area, mountainous stretches area, and urban area. Speed limit of state road or federal road is 80km/h, town area will be 60km/h. Due to some road condition, a 40km/h or 50km/h speed limit sign board will be placed in the area of having curve road.

Drivers suppose to stop at the intersection and observe the surroundings vehicle movement before turning to the another route. So, speed limit of intersetcion area will be set as 30km/h in this project to determine the drivers' speed limit condition. The intersection having traffic light will be applied with 35km/h speed limit. Drivers should not drive through the traffic light intersection area with high speed. In some circumstances, the driver will increase the vehicle speed when the traffic light of the intersection turned to amber signal. The driver will stop the car uncomfortably due to the insufficient time of amber period. The driver need to make decision at the stop-line either to pass through the intersection after red signals or brake hard in front of the intersection. This action will increase the potential of accident occurrences.(Kulanthayan, Phang, & Hayaticoncatenate, 2007)

LibreOffice is used to add on the speed test feature and the road condition feature. The driver name is also added to the vehicle operation data of the particular driver. Figure 4.5 shown the vehicle operation data after added on new features.

4.3 Driving Operation Data Preprocessing

The first 30 rows and last 30 rows of the collected vehicle operation data need to be removed. It is because drivers just come out from the parking at the beginning or drive into a parking slot at the end of the driving session. The removed data is always incomplete. Figure 4.6 shows the setting of CSV Reader module of the KNIME Analytic Platform to perform data preprocessing.

M	N	O	P	Q	R	S	T	U	V
Driver Name									
1	G(calibrated)	Speed (OBD)(km/h)	Engine RPM(pm)	Throttle Position(Manifold)(%)	Speed (GPS)(km/h)	Engine Coolant Temperature(°C)	Acceleration Sensor(Total)(g)	Road Condition	Speed Test
2	-0.05620438	0	869	13.33333997	0	84	-0.052043798	Straight Road	1
3	-0.05620438	0	884.25	13.33333997	0	84	-0.052043798	Straight Road	1
4	-0.052060558	0	884.25	13.33333997	0	84	-0.052060558	Straight Road	1
5	-0.055592928	0	884.25	13.33333997	0	84	-0.055592928	Straight Road	1
6	-0.04495579	0	882	13.33333997	0	84	-0.04495579	Straight Road	1
7	-0.04495579	0	878.5	13.33333997	0	84	-0.04495579	Straight Road	1
8	-0.04495579	0	872.75	13.33333997	0	84	-0.04495579	Straight Road	1
9	0.101343115	0	741.75	13.72540507	0	84	0.101343149	Straight Road	1
10	-0.02739529	0	721	13.72540507	0	84	-0.02739529	Straight Road	1
11	0.05363506	9	1554.75	23.13725471	0	84	0.0536350679	Straight Road	1
12	0.07398902	17	2068.75	27.05882454	4.277858454	84	0.0739890337	Straight Road	1
13	-0.02739529	22	2077	25.52200001	8.0870875306	84	-0.02739529	Straight Road	1
14	0.08468211	22	1198.75	12.94117641	19.23929596	84	0.08468210697	Straight Road	1
15	0.050841033	21	1038	12.94117641	20.77035665	84	0.05084103345	Straight Road	1
16	-0.052060558	21	1003	12.94117641	20.77035665	84	-0.052060558	Straight Road	1
17	0.015731871	17	810	13.72540507	20.5945477	84	0.01573187113	Straight Road	1
18	0.05641598	13	745	18.28801863	84	0.056415984	U-Turn	1	
19	0.02739529	11	715	13.72540507	84	0.02739529	U-Turn	1	
20	0.02739529	11	693.75	13.33333997	12.78856564	84	0.02739529	U-Turn	1
21	0.018521726	7	707.75	13.72540507	11.48134804	84	-0.0185217263	U-Turn	1
22	-0.02739529	7	715	13.72540507	11.48134804	84	-0.02739529	U-Turn	1
23	0.061116186	0	773.75	14.5098377	3.432104820	84	0.061116186	U-Turn	1
24	-0.04673648	0	760.25	13.72540507	1.670207494	84	-0.04673648	U-Turn	1
25	-0.06096929	2	824	16.078432026	0.751702202	84	-0.06096928777	U-Turn	1
26	-0.052060558	4	935	15.289513444	0.751702202	84	-0.052060558	U-Turn	1
27	-0.20121701	6	725.5	13.72540507	2.699998909	84	-0.201170097	U-Turn	1
28	0.039082887	5	709	13.72540507	5.04821588	84	0.0390828877	U-Turn	1
29	-0.02739529	5	725.5	14.5098377	0.02739529	84	-0.02739529	U-Turn	1
30	-0.076953036	4	761	14.11764717	4.541139603	84	-0.0769530347	U-Turn	1
31	-0.008482456	2	745.25	14.11764717	4.231811081	84	-0.00848245627	U-Turn	1
32	-0.02739529	1	781	14.11764717	4.231811081	84	-0.02739529	U-Turn	1
33	-0.011218161	0	765.5	14.5098377	1.634338472	84	-0.01121816154	Straight Road	1
34	-0.022411889	0	705.25	14.11764717	0.107999994	84	-0.022411889	Straight Road	1
35	-0.02739529	3	150.5	25.52200001	0.02739529	84	-0.02739529	Straight Road	1
36	-0.04249416	8	1743.75	26.66667974	2.04186964	84	-0.04249416	Straight Road	1
37	-0.023050509	14	1892.75	29.0196754	8.536869512	84	-0.023050509	Straight Road	1
38	-0.02739529	19	2346	30.31200001	17.5794843	84	-0.02739529	Straight Road	1
39	-0.015245669	22	297.75	33.33333209	17.5794843	84	-0.015245669	Straight Road	1
40	-0.028986812	27	3566.5	38.82352829	20.73615646	84	-0.028986812	Straight Road	1

Figure 4.5: The vehicle operation data is added on the speed test column and road condition column.

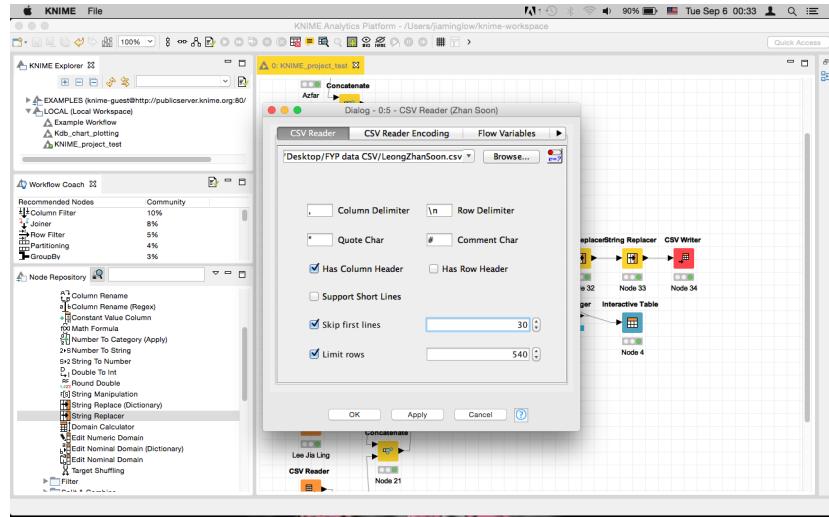


Figure 4.6: CSV Reader settings for data preprocessing.

4.4 Data Fusion

All the pieces of preprocessed data for each driver are required to be concatenated as a big table before performing clustering. In Figure 4.7, the processed data are concatenated by the concatenation module provided by KNIME.

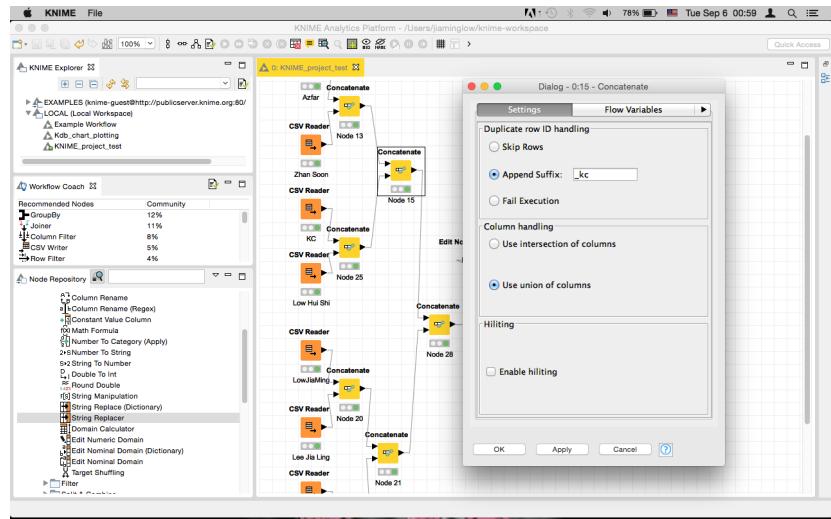


Figure 4.7: CSV files are concatenated by using the concatenation module in KNIME.

4.5 Establish the driving operation model by K Means Algorithm

A work flow will be designed and implemented by using KNIME Analytic Platform. The work flow will be able to input the vehicle operation data file and perform K Means Algorithm on the data set. The number of clusters can be 3, 4, 5 or more. However, three clusters will be identified through the work flow in this project. The three clusters will represent the good, medium, and bad vehicle condition data. In the end of this process, each vehicle operation record will be labeled with the good, medium, and bad vehicle condition data.

4.5.1 Features selection

Some of the features of the vehicle operation data is chosen to be used in clustering. Correlation module is implemented to help features selection. The correlation between the features are shown in Figure 4.8. The low saturation of the colors means that the correlation between the two features is low. According to the correlation result, the selected features include GPS Altitude, GPS Bearing, GPS Vehicle Speed (km/h), Engine Speed, Throttle Position, and Speed Test. Engine coolant temperature and acceleration sensor is removed as this two features do not have strong relationship among the rest of the features. The selected features will be used in clustering.

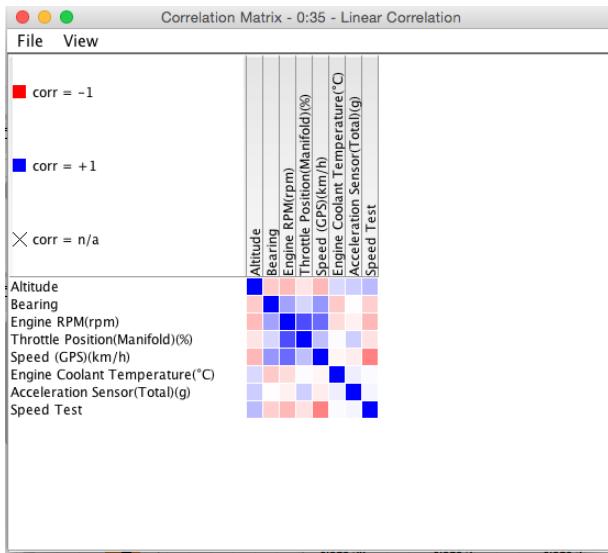


Figure 4.8: The correlation among the features

4.5.1 (a) *Linear Correlation*

Linear correlation is the straight line relationship between two variables. The range of the value of the linear correlation is between '-1' and '1'. If the value is '1', it means that the relationship is perfect positive relationship. The coordinates of the variables displayed on graph will be similar to a straight line with positive gradient. If the value is '-1', it means that the relationship is perfect negative relationship. The coordinates of the variable displayed on graph will be similar to a straight line with negative gradient. The '0' means no straight line relationship between the two variables.

4.5.2 *Cluster Labeling*

After the K Means Algorithm module execution, three clusters will be generated. Figure 4.9 shows the coordinates of the center of the three clusters. A hypothesis is made at this point. The hypothesis is that the speed test value approximates to 1 is good vehicle condition data. It is because the value of speed test equal to '1' means the driver followed the speed restriction of the road. Based on the speed test value, medium and bad condition data can be labeled to the cluster. So that, 'cluster_0' is good vehicle condition data. 'cluster_1' is bad vehicle condition data. 'cluster_2' is

medium vehicle condition data.

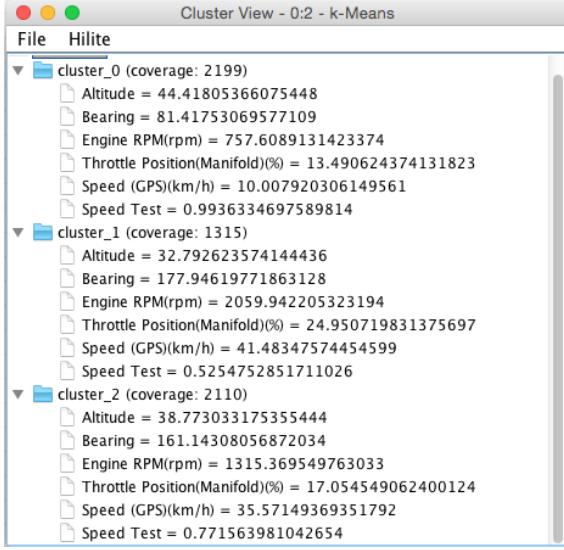


Figure 4.9: The coordinates of cluster center for each cluster.

String Replacer module provided by KNIME Analytic Platform is implemented to change the 'cluster_0', 'cluster_1' and 'cluster_2' to 'good', 'medium' and 'bad' accordingly.

Based on the declared hypothesis, all the records should be labeled as good vehicle condition data when the value of speed test for the particular records is '1'. Tableau is implemented to show the relationship between the speed test and the three clusters in figure 4.10. The result is 6 out of 2199 good vehicle condition data labeled as bad vehicle condition data. The hypothesis is accepted.

4.5.3 Work Flow Design

The completed work flow is displayed in the Figure 4.11. The CSV Reader is the module that allows CSV file to be inserted into the work flow and perform the data preprocessing at the same time. The Concatenate module will perform the data concatenation to combine the drivers vehicle operation data. The K Means Algorithm module will perform clustering to categorized the data into three groups. The number of groups is set in the module configuration. Figure 4.12 shows the configuration of the K Means Algorithm module.

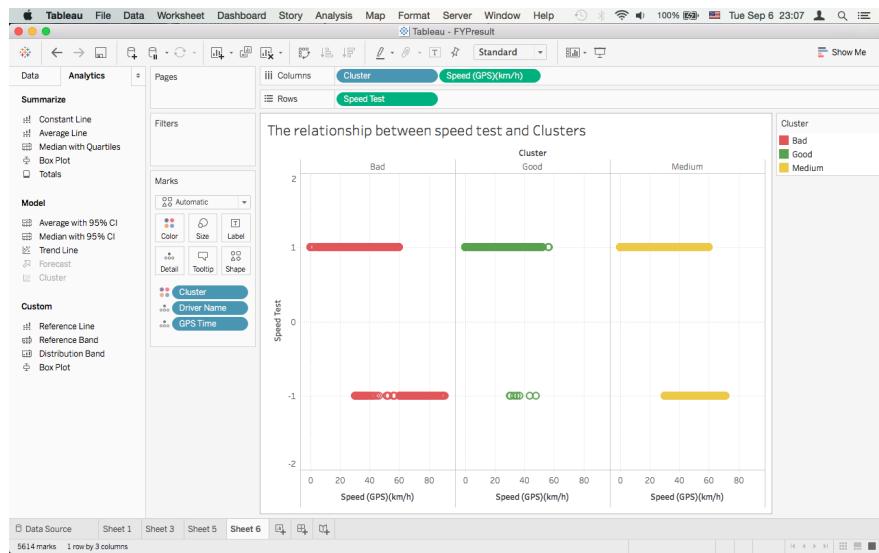


Figure 4.10: The relationship between the speed test and the three clusters.

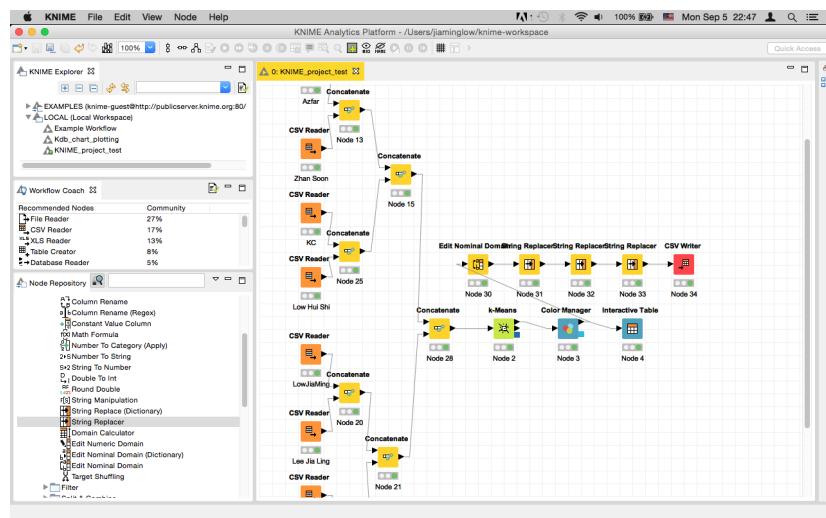


Figure 4.11: The completed workflow for classify the driving operation model.

4.6 Driver Driving Behavior Profiling

In this project, the driver driving behavior profile can be determined by some condition. If the total of good VCD is greater than the total of medium VCD and bad VCD at least 10% of the total records, the particular driver will be categorized as low risk driver. If the amount of good VCD do not fulfill the condition, the total of medium VCD and bad VCD will be chosen for classifying the driver. The total of medium vehicle VCD should over at least 55% of the total medium VCD and bad VCD, then the driver will be categorized as medium risk driver. Otherwise, the driver

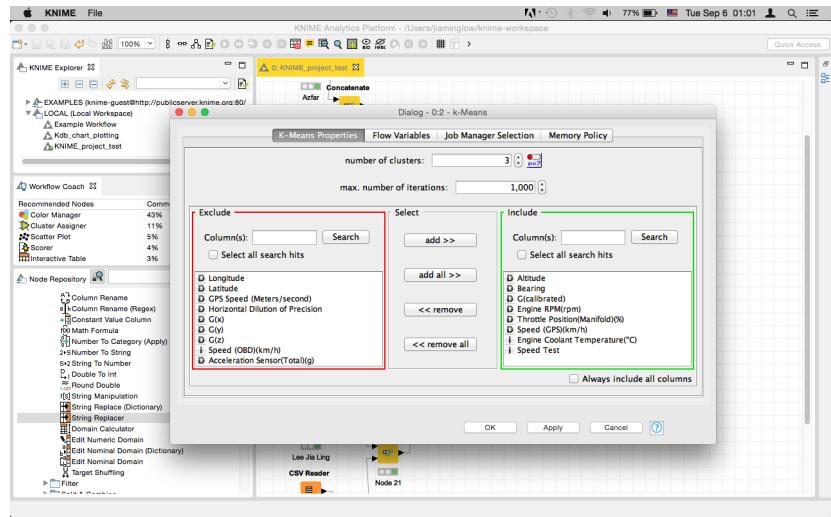


Figure 4.12: K Means Algorithm module setting.

will be categorized as high risk driver.

After trying few method to determine the driver driving behavior profile, this method is the most suitable among the method. It is because there are two comparison to be performed to get the driver driving behavior profile. The first comparison will determine whether the driver is low risk driver. In order to fulfill the condition of the first comparison, the good VCD should over 55% of the total records. If not, the rest of the records will be used for determining whether the driver is medium risk or high risk driver. The medium VCD is required to have 55% among the medium VCD and bad VCD, then the driver only can be categorized as medium risk driver.

The table 4.6 shows the result of the total number of driving records for each cluster and the driver driving profile.

One of the ways to determine the driver driving behavior profile has been tried. The method is using the average of the records among the three clusters to compare with the total amount of each cluster . If the good VCD exceeds the average point, the particular driver will be classified as low risk driver. It is same to every clusters.

This method is not suitable for determining the driver driving behavior profile

Driver	Good Model	Medium Model	Bad Model	Driver Driving Profile
Candidate 1	239	138	249	High Risk
Candidate 2	178	120	271	High Risk
Candidate 3	178	156	237	High Risk
Candidate 4	372	207	67	Low Risk
Candidate 5	553	294	95	Low Risk
Candidate 6	144	446	88	Medium Risk
Candidate 7	372	304	205	Medium Risk
Candidate 8	163	445	103	Medium Risk

Table 4.1: The result of the driver driving behavior profiling.

as there will have same cases difficult to classified the drivers' risk level. In Figure 4.13, Candidate 1 will be hard to classify the driver's risk level as the good VCD and bad VCD exceed the average at the same time. So, this method is not suitable.

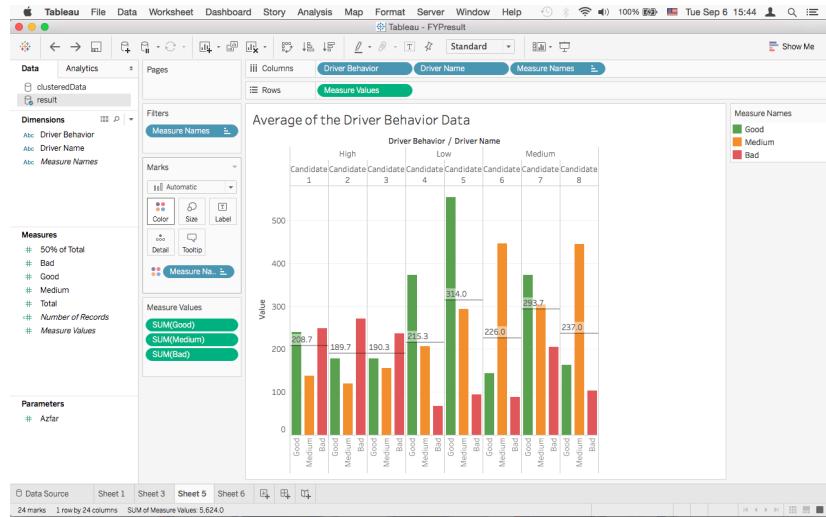


Figure 4.13: The result of the driver driving behavior profiling by using Tableau side-by-side bar with average point.

CHAPTER 5

IMPLEMENTATION PLAN

5.1 Project Problem Encounter

In this current phase of the project, the route of drivers drove through is inconsistent. It caused the speed limit condition is hard to be determined. It needs a lot of time to check the road condition and the speed limit at the particular path of the route by using Google Street View and Google Earth. The usage of speed limit Application Programming Interface (API) is not free. It is also unavailable to use without an Asset Tracking License.

5.2 Data collection

In the next phase of the project, there are three routes will be selected. The drivers will be requested to drive through all the routes. After the driving session, a proper questionnaire will be required to fill up by the driver. The questionnaire will ask about the driver basic detail and some driving history or background.

At least a month will be spent to collect the data in the next project phase. In order to train the machine for classifying the driver driving behavior, the amount of the data collected in the current project phase is still not enough.

5.3 Data Analysis

Since the paths for driving session is consistent, the work for labeling the road condition will be reduced. A proper speed limit labeling will able to be implemented. For the speed test feature, some cases are allowed for drivers to exceed the speed limit. For example, Driver A wants to overtake Driver B's car as Driver B is driving dangerously or the Driver B is drunk. The Driver A behavior will be considered as

low risk, although Driver A exceeded the speed limit. A lot of situations need to be considered and identified in the next phase of project.

5.4 Machine Learning Technique Implementation

Naive Bayes algorithms will be implemented in the next phase of project. The machine will be trained to classify the driver driving behavior by using the Naive Bayes algorithms.

5.4.1 Naive Bayes classifier

Naive Bayes is one of the most efficient and effective machine learning algorithms. It is a supervised learning algorithm. It assumes that the features are independent. Each features contribute to the probability to identify the classification independently. For example, a fruit can be classified as an apple based on the red color, circle shape, and the *6cm* in diameter. Although the features exist relationship among themselves, the features contribute independently in the probability that to identify the fruit is apple(Ray, 2015).

5.5 Project Plan of next project phase

In the next project phase, data collection is required a lot of time to be done. The papers related to Naive Bayes algorithm are needed to be reviewed in order to improve the understanding of the algorithms. The next project phase timeline is shown in Table 5.5.

Task \ Week	2	3	4	5	6	7	8	9	10	11	12
Literature Review											
Data Acquisition											
Data Analysis using KNIME											
Driver Driving Behavior Profiling											
Data Training using KNIME											
Analyzing Experimental Result											
Documentation and Report											
Report Submission											

Table 5.1: Project timeline of Final Year Project II for Trimester 2 2016/2017

CHAPTER 6

CONCLUSION

6.1 Introduction

In the current project phase, normal driver driving behavior profiling can be achieved by using the KNIME. However, the method described in this project is needed to be enhanced. A model should be trained for machine learning. In the future, a new driver vehicle operation data will be able to be classified without clustering.

6.2 Conclusion

Driver driving behavior profiling using vehicle on board diagnostic (OBD) information and K Means Algorithm is described in this project. OBD interface and smartphone are utilized to collect vehicle operation data and GPS data. According to the value of linear correlation among the features of the vehicle operation data, some of the features are selected to be used in K Means Algorithm for clustering. The selected features contain GPS Altitude, GPS Bearing, GPS Vehicle Speed (km/h), Engine Speed, Throttle Position, and Speed Test.

Each vehicle operation record is labeled as good, medium or bad condition according to the clusters. Each driver will be categorized to three groups based on the number of each condition the driver had. In the next project phase, this method will be implemented in order to train the machine to classify the drivers.

APPENDIX A

MEETING LOG

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