Vehicle Distance Measurement Tuning using Haversine and Micro-Segmentation

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***Abstract*—In the globalization era, the vehicle tracking system is important and it is needed in the fleet asset management system. This management system has a significant role in good logistics distribution in order to measure mileage of truck traveling. Therefore, the existence of the global positioning system (GPS), information system, and network technology can help to monitor the fleet system. GPS devices, from anywhere and anytime, send JSON information by POST method in HTTP to the information system server through internet connection. Furthermore, the stakeholders, the customer and the company of fleet service, can measure the real distance which is gathered from GPS. Contribution of this research is to find the best distance measurement gathered by micro-segmentation technique and summarization of each segment by Haversine formula. Micro-segmentation in this research is performed by modification of how often data sent to the server. Furthermore, we use RMS value that shows correlation, which is obtained by comparing our system result to the real odometer, Google Maps, and GPS data measurement. The obtained RMS of our system exceeds 0.9005 which compared to GPS data. From the result we obtain most optimal repeat duration for sending data by tuning duration with value of every 30 seconds.**

Keywords*—*fleet, GPS, Haversine, micro-segmentation,

I. Introduction

In the current era of globalization, transportation is a very important need of our live. Delivery of goods, which are part of transportation services, increases business competition in the logistics and IT area. In terms of shipping goods, both abroad and domestically, trucking services play a very important role. The trucking service companies calculate the cost of the delivery by considering the goods weight capacity, distance of delivery, and also some hidden cost. Many companies and individuals have used trucking services to deliver many goods in large quantities. Trust in utilization of trucking services in good delivery has made rapid development of fleet management field. It is an important need for increasing the efficiency of communication between the truck driver, control centers, and customers, which run smoothly [1].

Tracking system using GPS, which is based on Internet of Things (IoT) provides effectiveness, vehicle location in real time, mapping, and real-time information report to the control center, so that it will improve the quality of services [2]. The information system in this research provides the customer with information of the current location of the truck, traveled route, and real-time vehicle speed using the latitude and longitude movement estimation and geographical time information from the GPS.

This research provides a truck tracking information system in two forms, which are a web-based application and the Android environment. The hardware system consists of GPS, which is permanently installed in the vehicle and connected to vehicle accumulator. It is a GPS tracking device with GT06-A protocol. The GPS device continuously obtains the vehicle location in real time and then sends updates in JSON format to the server. The output of this information system can be accessed not only by fleet service customers to get the exact current location of the delivery truck but also by the management of fleet system in the admin section side. The both stakeholders can track the vehicle according to its path.

The remainder of this paper is organized as follows. In Section II, some related works of the same fields are provided. In Section III, we exhibit the conducted methodology. In the next section, we describe evaluation procedure of our system performance. Finally, in the last section, the conclusion and future work are provided.

II. Related Work

There are many types of research that harvesting GPS data and do some calculation to ensure the data is properly representing track or route of the vehicles, as follows.

In [1], the authors studied about harvesting point of interest from GPS trajectories data. Point of interest could be formed by sharing GPS logs among some peoples. Point of interest is used to find some places that attract user, based on another user route. Their research uses Haversine formula to calculate the distance between the start position of the user and the end position of user. The end position of the user at some latitudes or longitudes show that user visits some interesting place such as tourism destinations. The system can make a recommendation of tourism place based on region closeness between user current location and point interest that gathered and clustered by the system.

Different from [1], in our research, the Haversine formula is combined with micro-segmentation from GPS data record to measure distance of the truck route. Furthermore, in [1], the distance is directly measured between two points. Meanwhile, in our research the distance is summarizing a little distance from each point of the GPS data received.

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In [2], the authors studied about underestimation which is happened in distance calculation of GPS data. They proposed micro-segmentation technique to overcome the displacement problem. Micro-segmentation can improve the accuracy of distance measurement significantly. Two factors that affects this technique are the frequency of GPS trace update and the curvature or the number of turns in the road segment. The error possibility of micro-segmentation is caused by the turnover section of the road that not detected. The authors utilize a high precision GPS device. Meanwhile, micro-segmentation of our research is applied in low-cost GPS device, i.e., GT-06A, that sends data with GSM connectivity to the GPS server.

In [3], the authors studied IoT powered vehicle tracking system. The tracking system developed with geofence technology in the purpose of ubiquitous fleet tracking with maximum accessibility for anytime and anywhere utilization. The proposed system provided dynamic fleet management with constant tracking which triggers the safety and security along with reduced operational cost and avoidance of illegal usage. The authors didn't use the Haversine formula for distance calculation. They used default geofence functionality from Traccar software. There is no further testing for the usability of geofence technology. Geofence is not applied in our research because the main purpose is to calculate the error of distance. The error of distance could become one factor of price estimation calculation for delivering the good. Another factor of price estimation such as traffic jam that causes fuel consumption differentiation is not rather discussed in this research.

In [4], the authors compared great circle distance method which are Vincenty and Harversine. The former has better performance than the latter on over speeding detection. The Vincenty equation can accommodate earth's surface condition that has ellipsoidal shaped. Furthermore, the accuracy of the monitoring system can be enhanced with the increasing of frequency of position reporting. In our research frequency of GPS position data reporting is variated to get best Haversine and micro-segmentation accuracy.

In [5], the authors studied real-time update of the advanced public transportation system. Location report must be real time to estimate bus arrival time. GPS based tracking device is used and is reported every 1 second to the cloud database. The authors used Haversine to calculate the distance between two consecutive points. This is happened because some bus-stop have been plotted in the map. The Haversine formula is only for calculating two bus stop location so it is not estimating the real route. In our research, segmentations are important because there is no stopping station for the truck. The aim of our research is focus on the exposing of the current location of the truck and the estimated distance from start to the end position of delivery.

III. Methodology

The proposed system consists of three parts. First part is a tracking device that sends data through 3G/4G cellular internet connection to the server with POST data. The second part is a web application that shows database of latitude and longitude filtered by order. Web application uses Javascript technology to draw polyline for a route that truck goes through and draw a marker for the latest position of the truck. The third part is Haversine and micro-segmentation calculation to estimate the total distance of truck travel. Calculation of

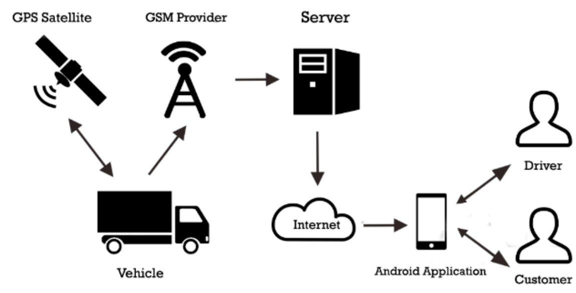

Fig. 1. System design of the truck tracking management

Fig. 2. GT06-A component which is equipped in truck.

Haversine and micro-segmentation are compared to real measurement instrument like odometer and intelligent base calculation with Google Maps route estimation. This maps route estimation use contraction hierarchies that known to be highway hierarchies [6]. Fig. 1 exposes the overall system of truck fleet management. All information from latitude, longitude, GPS distance and also the order from the system are uploaded to the server and displayed in web interface and Android application.

A. Tracking Devices

GPS tracking device labeled with product name GT-02A and also recognized as GT-06A protocol, which combines 3G/4G, GSM, GPRS and GPS networks technologies. The device is useful for managing multiple security, positioning, and tracking functions. This GPS can determine the position and track remote targets via SMS or internet devices. The GT-06A hardware component is shown in Fig. 2. Information about GT-06A communication content is shown in Table I.

Date time information is represented by a hexadecimal value that converted to the decimal value to get a real date. Length of GPS information field is value of 1 byte displayed by two hex digits, where in the first one denotes the length of GPS information and the second one indicates the number of the satellite positioning, respectively.

Latitude is represented by four bytes that represents the latitude value of location data. The range of the value is 0-162000000, which indicates a range of 0°-90°. Longitude is also represented by four bytes that defines the longitude value of location data. The range of the value is 0-324000000, indicates a range of 0°-180°. The conversion method is converting the value of latitude and longitude output by GPS module into a decimal based on a minute, then multiplying the converted decimal by 30000, and converting the multiplied result into hexadecimal.

TABLE I. LOCATION DATA PACKET GT-06A PROTOCOL

Format			Length (Byte)	Example
Information Content	Start Bit		2	0x78 0x78
	Packet Length		1	0x1F
	Protocol Number		1	0x12
	GPS Information	Date Time	6	0x0B 0x08 0x1D 0x11 0x2E 0x10
		Quantity of GPS information satellites	1	0xCF
		Latitude	4	0x02 0x7A 0xC7 0xEB
		Longitude	4	0x0C 0x46 0x58 0x49
		Speed	1	0x00
		Course, Status	2	0x14 0x8F
	LBS Information	MCC	2	0x01 0xCC
		MNC	1	0x00
		LAC	2	0x28 0x7D
		Cell ID	3	0x00 0x1F 0xB8
	Serial Number		2	0x00 0x03
	Error Check		2	0x80 0x81
	Stop Bit		2	0x0D 0x0A

Speed is represented by one byte, which refers the running speed of GPS. The value ranges from 0x00 to 0xFF indicates a range from 0 to 225km/h. Course status is denoted by two bytes that indicates the moving direction of GPS. The value ranges from 0° to 360° is measured in clockwise path from north value of 0°.

After the network connection is established, a login process connects the GPS device to the server by validating GPS device information and protocol. Afterwards, the GPS device will send POST parameter using HTTP and update the data to the database system respectively. POST parameter criteria and testing captured by Wireshark is shown in Fig. 3.

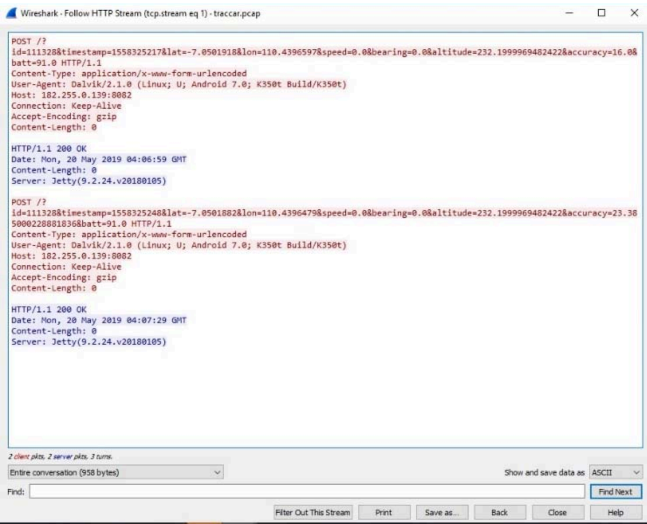

Fig. 3. Wireshark analysis of GT-06A POST parameter

B. Javascript Polyline Method

Javascript is utilized in Google Maps API environment to read MySQL database using Ajax technology. The Ajax technology is used because every searching the order, the data need to be read. Data from the database can be loaded to an array by looping function and push method. This is the piece of function that can push data to an array and must be inside the looping scenario.

```
cords.push(new google.maps.LatLng(parseFloat(latitude[i]), parseFloat
(longitude[i])));
```

An array of latitude and longitude used in drawing method. Drawing method that could be used in Google Maps API is a polyline method. Polyline method can connect one point of latitude and longitude to another point. This is an example of a polyline method defined in the application.

```
var peta = new google.maps.Map(document.getElementById("map-canvas"),
petaoption);

polyline = new google.maps.Polyline({path: cords,geodesic: true,strokeColor:
'#337ab7', strokeOpacity: 1.0, strokeWeight: 3. });

polyline.setMap(peta);
```

Polyline can be combined with a marker. Marker can be used to display the current position of the truck and some information like when last GPS data was updated. Polyline and marker could be rendered if we firstly defined the variable for the maps and place the maps inside the HTML canvas.

C. Haversine Formula

Haversine Formula is a method for knowing the distance between two points by assuming that the earth is not a flat field. Earth in Haversine is a field that has a degree of curvature. The Haversine Formula method calculates the distance between 2 points based on a straight-line length between 2 points on longitude and latitude. The formula basically ignores the ellipsoidal form of the earth. Haversine assumes that the earth is a ball and ignores the height of the earth and the depth of the valley on the surface of the earth. In fact, we know that the shape of the earth is in the form of an ellipse. For the earth, the minor axis passes through the pole and has an estimated polar radius of 6356.7523142 km. The main axis is equivalent to the radius on the equator with an approximate radius of 6378.137 km. Therefore, in order to calculate the distance using Haversine Formula in applying the ellipse-shaped earth, the value of the radius of the earth circle must be known if the position of the coordinates is not on the equator. Following is the basic form of Formula Haversine.

$$2R.sin^{-1}\left(\sqrt{sin^2\left(\frac{lat_2-lat_1}{2}\right)+\cos(lat_1).\cos(lat_2).sin^2\left(\frac{long_2-long_1}{2}\right)}\right) \quad (1)$$

where that R denotes the radius of the earth (radius = 6,371km), lat is latitude, long is longitude, lat_1 refers the latitude of the start point. $long_1$ is longitude of the start point, lat_2 represents the latitude of the endpoint, $long_2$ is the longitude of the endpoint. In order to obtain the value of R (the radius of the earth) we can use the following formula.

$$R = R(\emptyset) = \sqrt{\frac{(a^2.\cos(latitude))^2+\left(b^2.sin(latitude)\right)^2}{(a.\cos(latitude))^2+\left(b.sin(latitude)\right)^2}} \quad (2)$$

where *a* is equatorial radius, and *b* is polar radius

D. Micro-Segmentation Technique

The micro-segmentation method is used to calculate distance. The algorithm is repeatedly applied for all consecutive pairs of traces (T_{i-1}, T_i) in the set T^1, for calculating the distance between T_{i-1} and T_i and the results were stored.

GT06-A does not give exact kilometers for short route. Micro-segmentation is not supported directly in GT-06A devices. Distance for two points could be derived from the speed of the vehicle and time GPS sent the data. If the frequency of sent data is too close, then the speed of the vehicle is not giving exactly value. Optimization of this method could be gained by combining micro-segmentation with Haversine calculation. The algorithm is the same as micro-segmentation technique but using Haversine in each consecutive pairs of traces. For testing the accuracy, different frequency of sending data is applied.

Method specification explained on following terms: (a) get the best time interval that not very often but has an optimal accuracy (micro-segmentation technique), which is chosen is every 30 seconds, (b) apply Haversine formula in eq. 1 to every point gathered from GPS devices, and (c) testing with a variation of distance and comparing with Google API distance and GPS own calculated distance.

IV. Evaluation Procedure

The GPS sampling test is the first performed test in our research. At this stage, the GPS that has been sending data to the server, is evaluated for time lags in taking data with time in seconds. After there are no lags in the frequency of delivering data, there were testing carried out several times to determine sample in obtaining the best data retrieval interval. Testing is performed by comparing the data retrieval frequency every 3 seconds, 15 seconds and 30 seconds. Result of error does not change significantly for 30 seconds data retrieval. Variation of the distance that carried out are from 12, 15, 16, 22 and 23 kilometers. Web information system design of the overall system is shown in Fig. 4. The latest position of truck is exposed on the red truck icon. Moreover, there are trajectories that shown by a blue polyline.

Odometer is a measurement instrument that is used to compare the result of distance measurement. Odometer's measurement taken by the camera when the vehicle arrived at the destination. Moreover, Google Maps Route is used as comparison. Google Maps Routes use its proprietary algorithm that computes the distance based on vehicle type, traffic of the road, and get the fastest route by applying highway hierarchy algorithm. GPS speed and distance are the original calculation comes from the device. Beside longitude and latitude, the devices send distance information based on speed and time that device sent the data. All the measuring distance and comparing factor are compared to the proposed calculation methods, which are Haversine and micro-segmentation. Table 2 exhibits the result of variation in distance and device ID where data were taken.

The obtained GPS data in Table II can be derived for comparison by using the root mean square (RMS) value. This RMS value shows that one measurement has a correlation to another. The plotting of RMS of odometer and Haversine formula, Google maps and Haversine formula, and GPS distance and Haversine formula are shown in Fig. 5, Fig. 6 and Fig. 7, respectively

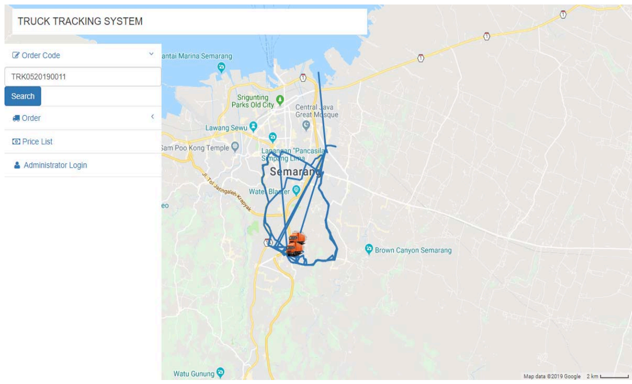

Fig. 4. Dashboard of the truck tracking system

TABLE II. GPS Measurement Comparisson

GPS Devices ID	Odometer (km)	Google Maps Route (km)	GPS Speed and Distance (km)	Haversine and Microsegmenting (km)
1	12.00	12.20	11.08	11.73
2	23.01	21.10	23.20	27.56
3	13.15	13.80	12,93	12.39
4	15.80	16.40	15.80	15.68
5	22.39	21.10	23.20	20.45
6	16.00	16.40	16.30	20.87
7	12.00	12.20	11.08	11.72
8	13.50	13.80	12.01	12.18
9	2.23	2.10	1.89	2.18

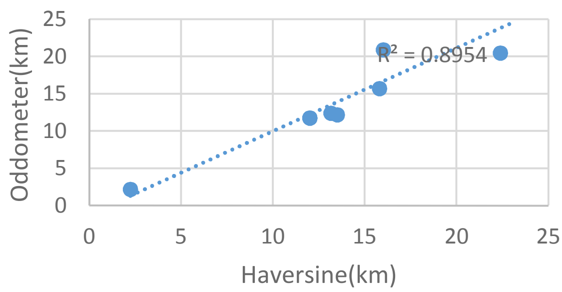

Fig. 5. RMS between Odometer and Haversine

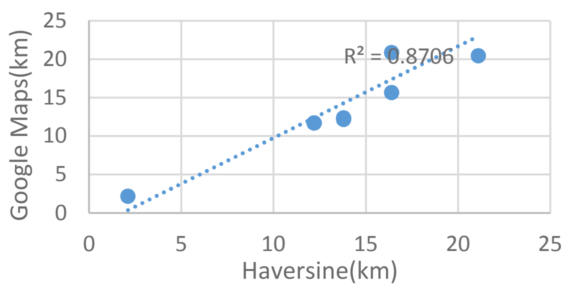

Fig. 6. RMS between Google Maps and Haversine

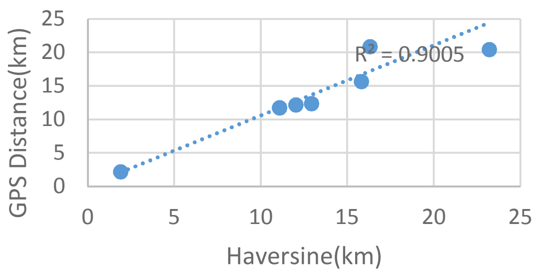

Fig. 7. RMS between GPS distance and Haversine

TABLE III. GPS ERROR COMPARISSON

Device ID	Odometer and Haversine (km)	Google Maps and Haversine (km)	GPS distance and Haversine (km)
1	0.268944	0.468944	0.651056
2	5	6	4
3	0.764358	1	0.541357
4	0.122851	0.722851	0.122851
5	2	0.650421	0.750421
6	5	4	5
7	0.277249	0.477249	0.642751
8	1	2	0.166052
9	0.052648	0.077352	0.287352
Mean	1.575350	1.819206	1.344396
SD	1.885885	2.180792	1.785901

Analysis of RMS values show that Haversine has the closest value with GPS original distance data. Odometer as measuring instrument has an error because most odometers work by counting wheel rotations and assume that the distance traveled is the number of wheel rotations times of the tire circumference.

Google maps have calculated many factors, so the RMS is farthest from Haversine formula. The RMS also explained that there is a different factor that cannot be captured from the Haversine measurement. Overall measurement shows that the lowest RMS is 0.8706. Furthermore, analysis of error is shown in Table III. From the table we obtain that higher mean value is obtained in comparison between Haversine and Google Maps, Moreover, the standard deviation of error shows that variation of distance contributes to the variation of error.

V. CONCLUSION AND FUTURE WORK

In this research, we propose a tuning mechanism for Haversine and micro-segmentation if in GPS device not fully supported the distance in near points. Frequency of sending data could be set to 30 seconds according to error evaluation. Variation of kilometers contributes the error based on the standard deviation analyzed. Google Maps has a certain factor like traffic estimation and movement behavior so distribute the highest difference with Haversine and micro-segmentation. The root means square error shows that there is 12.94% (1-0.8706) of an undescribed factor when comparing Haversine and Google Maps. Moreover, the closest RMS value of Haversine is obtained by comparing to value of GPS, with value of 0.9005.

Micro-segmentation tuning could be done by calculating every distance gathered from GPS every 30 seconds with Haversine formula. Haversine formula although does not very accurate like Vincenty, it has a contribution in computational complexity because only use one formula rather than iteration. For future work, several improvements could be done. Low-cost GPS have a certain problem as if the power resource is not well supplying the power, the data sent is lost in many seconds. If the signal of GSM is lost then we could propose some methodology based on accelerometer and gyroscope estimation of vehicle movement to obtain the predicted position.

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