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Performance Analysis of Traffic Counting and the Vehicle Classification Using AMR Magnetic Sensors

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ABSTRACT
Counting and classification of vehicles is a problem that must be solved in addressing traffic congestion. The number of vehicles passing through a road affects the level of traffic density, whereas the type of vehicle required for sorting lanes are allowed to pass certain types of vehicles. This paper will discuss AMR magnetic sensor capabilities to solve problems in the counting and classification of vehicles. This study uses 2 AMR sensor for measuring the magnetic field turbulence vehicle. Testing the system produces a vehicle speed detection accuracy above 90% and the system of counting the number of vehicles is 100%. The relative error of the first phase of vehicle classification between + 5% - + 10% and the relative error in the second phase for vehicles entering the incision group was + 36.4%.
***Keywords* -** Counting of vehicles, Vehicle Classification, AMR Sensors, Microcontroller, Zigbee.

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I. INTRODUCTION

The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

Congestion in large cities is a classic problem and happens every day. The increase in the number of vehicles continues to occur, but it is not directly proportional to the increase of the highway. Highway growth very hard done by because of the density of buildings. The value of loss due to congestion is so great, that the cost of wasted fuel as well as the operating costs of the vehicle. Another impact of the congestion for example wasted work time, air pollution and stress for road users. To reduce congestion occurs, one solution with increasing the efficiency of the use of roads, namely the management of traffic in the intersection of the roads by creating Automatic Traffic Light Control System (ATCS). ATCS will determine the long green lighting automatically based on density. Source data obtained from ATCS detection system the number of vehicles automatically.

A variety of methods are used in the manufacture of vehicle detection system. Such methods are divided into two group i.e. intrusive or non-intrusive [1]. Intrusive, usually directly mounted on the body of the highway, by creating a hole as a place of laying tools/sensor, while the method is non-intrusive, not installed/planted on the highway but the side of the road. This research, the author would like to propose an alternative system for the detection of the number of vehicles, vehicle speed and classification of vehicles in real time, using sensors anisotropic magneto-resistive (AMR). The medium of communication between the sensors with the server/computer-based wireless, namely using zigbee (IEEE 802.15.4.).

AMR sensors is one of a good sensor for sensing do to changes in the magnetic field of the Earth, be it linear and angular position measurement and also the shift in Earth's magnetic field. AMR sensors are made of iron-nickel (Permalloy), thin films deposited on silicon wafers and patterned as the resistive strip [2]. The ability of the sensor with a small power consumption, low cost, small size, high sensivitas, immunity to noise, easily assembled and its reliability make this sensor has many advantages.

Vehicles are generally made from metal, so when a vehicle passes through a particular area then the vehicle will do the turbulence in the Earth's magnetic field [3]. In Figure 1, shows an Earth's magnetic field flux will be exceeded by an object (car), when the object enters the area of the magnetic field then the field flux will experience turbulence. Changes in Earth's magnetic field turbulence can only be affected by objects that contain metal examples of cars, motorcycles, trains and planes.

Figure 2 is an illustration of the signal output from the sensor is AMR. At the time of the vehicle entering the area of coverage the sensor, the sensor will then issue the analog signal output amplitude voltage value specific to the time.

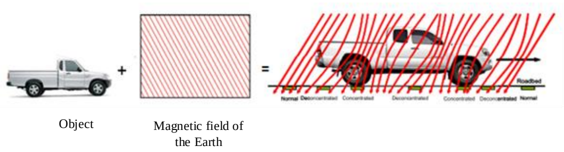


Figure 1. The magnetic field of the Earth affected by car [4]

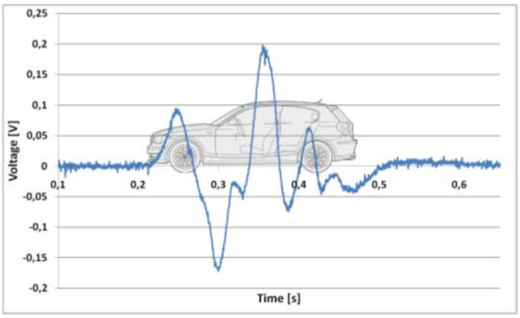


Figure 2. AMR Sensor Output curve [4]

Some research has been done to the vehicle detector, typically for counting, classification, plate recognition, speed and parking. Special studies that do classification, counting and vehicles speed, as well as camera-based sensors can by using method/algorithm. There are several types of sensors that can be used to detect vehicles. Based on the nature of each sensor, then the mounting/installation in the field will follow the sensor characteristics. Below, the author explains a little example of research that uses magnetic sensors.

Cheung. et. all [5], in his research for classifying vehicles, using magnetic sensor 2-axis, i.e. Z-axis and the X-axis. The classification success percentage of 60%. The method they use i.e. compare a cross between pattern hill between the 2nd axis. Introduction based on the hill pattern that is, if there is a slope value and amplitude exceed a positive threshold then the value 1 and 0 if less than the threshold and the reverse slope negative (-1) is also the same. Different vehicle types will have different pattern hill on the same axis. If there is a hill in the same pattern will then be compared to the hill on the other axis pattern (X). Still in the same study by Cheung Yiu Sing et.al., the results for counting vehicles is very good because it reached 99%. Error 1% because the vehicle came not pass right above the sensors mounted on the road. This indicates that the sensor is very sensitive of AMR, which can detect the presence of vehicles with either.

The sensor system consists of wireless anisotropic magnetic devices that do not require to be embedded in the roadway-the devices are placed next to the roadway and measure traffic in the immediately adjacent lane. An algorithm based on a magnetic field model is proposed to make the system robust to the errors created by larger vehicles driving in the nonadjacent lane. These false calls cause an 8% error if uncorrected. The use of the proposed algorithm reduces this error to only 1%. Speed measurement is based on the calculation of the cross correlation between longitudinally spaced sensors [7].

Iswanjono. et.al. [8], in research to detect the number of vehicles performing traffic light offences using RFID technology. The success rate of counting the number of vehicles was 100% at a speed of up to 150km/h.

Magnetohydrodynamics (MHD) can increase vehicle speed detection with increasing Gc, Gr, m and K, and it decreases with increase in Sc,M, n and Pr, temperature decreases with increase in Pr and n. [8].

A focusing on problems of gathering parameters of a traffic flow using simple sensors. The first part of the paper describes properties of a sensor node based on a magnetometer. The influence of various parameters (vehicle velocity, sensor location and orientation) on sensor output has been evaluated. We found that the sensor is sufficiently sensitive to be located on the road verges. In the second part, the sensor is used for vehicles classification based on estimate of their length. Velocity of vehicles is measured by a speed trap. The results of classification are compared with measurements where the velocity of vehicles is just estimated [9].

II. RESEARCH METHOD

Manufacture of the system, as a whole to perform several functions, namely:
1. Detection of the speed of the vehicle
2. Count the number of vehicles
3 Classifies vehicles based on vehicle class
4. Sending data from a microcontroller to computers using wireless, zigbee.

Generally, tools/components that will be used, namely: AMR Sensor (HMC 1001), ATmega Microcontroller, LCD 2x16, XBee series 2, laptop. Software/programming language is C, XCTU (for XBee), VB 6.0 (display on the server) and method for vehicle classification using decision tree based on parameter-parameter. Figure 3, is a work flowchart system generally connecting all over the device.

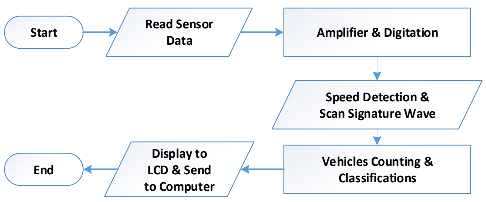


Figure 3. Flowchart system works.

Mounting the sensor in this research will be placed/planted in Street (intrusive), it is tailored to the type of sensor being used namely HMC 1001 (Figure 4).

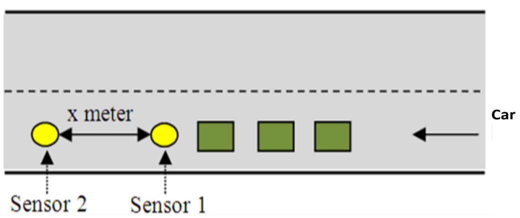


Figure 4. Installation of the sensor on the road.

Before you create the main program then to do sampling. Retrieval ample here is take the magnetic waves signature vehicles of several types of vehicles (in accordance with the) at various speeds. The data will be analyzed offline, to determine the parameters to be used in classifying vehicles.

Figure 5, is an illustration of a signature car magnetic field wave and wave parameters are to be taken. The creation of the program for sampling, already part of the making of the main program. The difference with the main program is not yet having a classification system and counting.

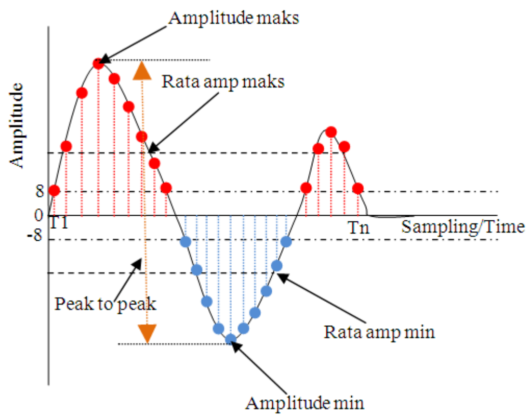


Figure 5. Vehicles Wave parameters are taken

When a vehicle is moving above the sensor, will give rise to changes in the magnetic field. The length change of the magnetic field which exceeded the threshold depends on the length and speed of the vehicle. So in data retrieval, will also be taken on how long the magnetic field (empirical duration) arising during the vehicle is moving above the sensor. The empirical duration compared to the duration of the vehicle above is mathematically a point (sensor). To calculate the duration of mathematically a moving vehicle, using equation formula of speed. If the dimension of X is the length of a car S meters, moving at velocity V km/h, then:

$$t(ms) = \frac{S.3600}{V}$$

III. RESULTS AND DISCUSSION

3.1 Results

Before you create the program, then it must first understand the characteristics of the magnetic sensor output HMC 1001. Objective to determine the start-stop system and specify the threshold values. Figure 6, 7, and 8 are the output voltage patterns, when it detects a moving car on the top (citycar : Suzuki Karimun, family car: Toyota Innova, and sedan: Toyota Baleno) at a speed of + 5 km/h.

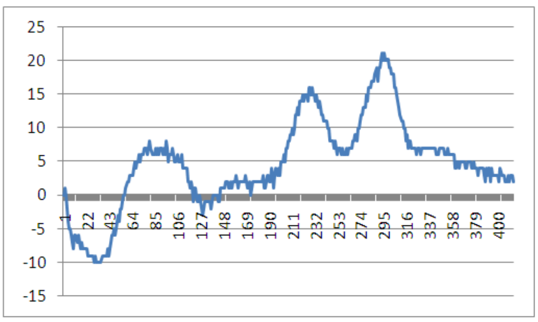


Figure 6. The sensor detection output of Suzuki Karimun.

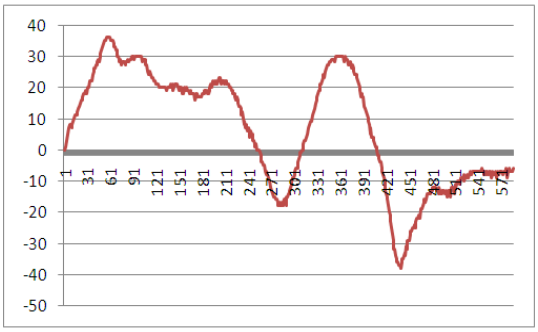


Figure 7. The sensor detection output of Toyota Innova.

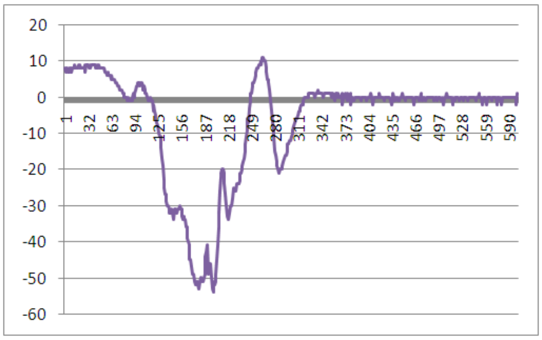
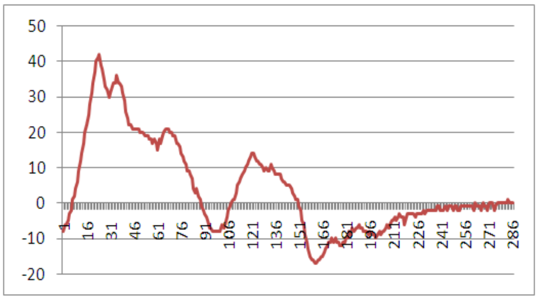


Figure 8. The sensor detection output of Toyota Baleno.

Determination of the amplitude value as the value of the threshold, that the system started working (start) must be taken into account by the fluctuating amplitude when the sensor has not detected the car. So in this study, the authors set the threshold value on the number + 8 and-8. If the value of the output of the sensor on the amplitude + 8/-8 then ensured the sensors detect the presence of the car, and the system starts working and it will stop when it is smaller than the threshold value. Figure 9 is the wave pattern output voltage sensor detects the car Toyota Innova at some speed, the faster the vehicle then the wave pattern of the magnetic field is getting closer.



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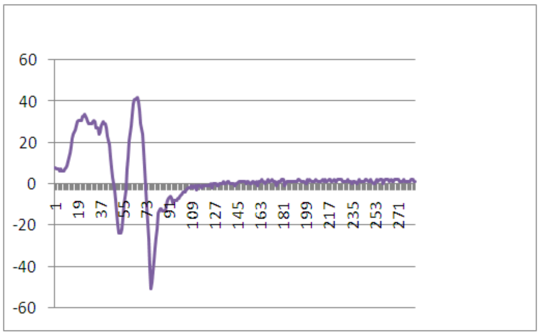

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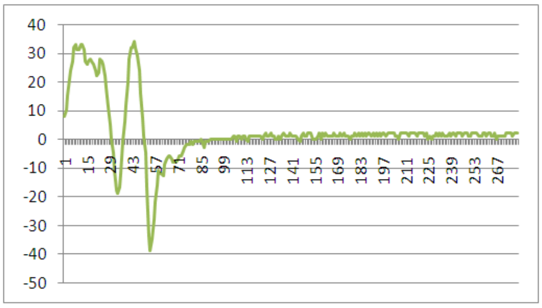
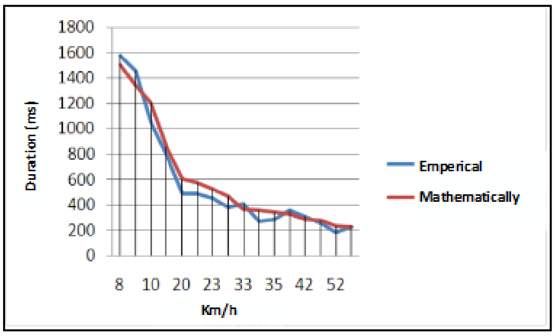


(c)

Figure 9. A wave pattern of Innova, the speed of a). 20 km/h, b). 40 km/h, c). 60 km/h.

Figure 10 is a chart of some test car, at different speeds (in random order). Duration/time empirical data sensor_1 detecting the magnetic field of a car, compared to the duration of the mathematically.



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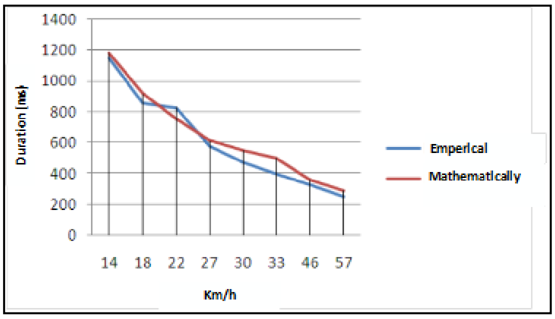

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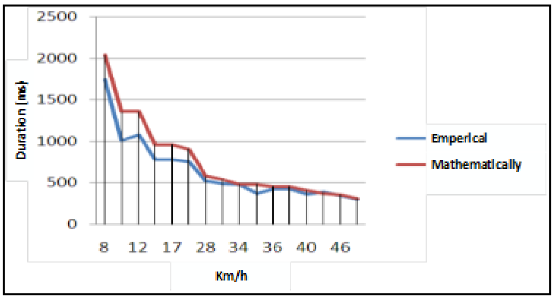

(c)

Figure 10. Graph comparison ofeEmpirical and mathematical durations (a) Suzuki karimun; (b) Toyota Innova; (c) Toyota Baleno

3.2 Discussion

3.2.1 Vehicle Speed Detection

In earlier research, Taghvaeeyan and Rajamani [6] to detect the speed of the car, the distance between the sensors 0.9 metres and Ondřej Karpis [9] at a distance of 2 meters. In this study, the authors performed a series of tests on some variation of the distance, i.e., 3 meter, 2 meter, 1.5 meters, 1.3 meters and 1 meter. The purpose of testing on some variation of distance, to fit with the system of "count the number of vehicles". Results from testing the detection speed give satisfactory results on all variations of the distance. Where there is no significant difference between the speed indicated on the car and the speedometer unreadable on your computer (by the sensor). Based on the analysis of the system "counts the number of vehicles", the author sets the distance between the sensor for this system is approximately 1.3 meters above the success and accuracy of + 90%.

3.2.2 Vehicle Counting

The counting system of the vehicle, must be able to work properly i.e. don't do recount against the same vehicles in field conditions, such as vehicles or articulated vehicle that stopped right above the sensor. Or count 1 on vehicles is different with each other following the (too close). So in this study focused on the maximum distance between the nearest vehicles are hand in hand so that the calculation is not wrong.

The system will deliver results if it has fulfilled the conditions of the limitation of the duration of the anchoring at sensor_1 and sensor_2. If the distance between the sensors is 3 meters at a speed of 5 km/h, then the new system will be ready to work for a vehicle following behind him, if the closest distance between the vehicles of a maximum of ± 4.3 meters. With the distance, likely there are vehicles that followed at a distance less than 4.3 meters. This can lead to miscalculations, including the classification of the vehicle. To anticipate these things, then the distance between the sensor_1 and sensor_2 should be brought. After doing a test on some variation of the distance, then the distance between the sensors is right for this system is 1.3 metres, because it has the time on timer_1 and timer_2 "On" is simultaneously the least. The car was used as a reference for observation is Suzuki Karimun on speed 5 km/h, due to the small-sized cars so that the magnetic field surrounding a small also. Thus the author gives the longest duration to both timers to control both of these sensors is 500 Ms. this system works as a whole, can be described in the form of diagrams of time in Figure 11.

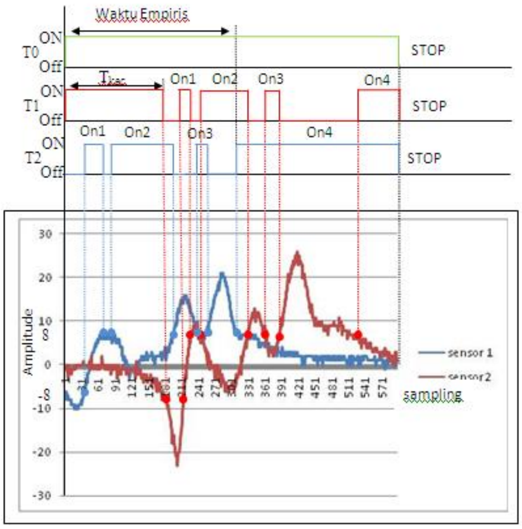

Figure 11. Time diagram of system working.

The system started working when the sensor_1 detect the magnetic field exceeded the threshold. Timer_0 and timer_1 to start counting time and system (sensor_1) doing scanning to get the values of the parameters. Counting by Timer_0 to get the empirical time or length of the sensors detect the vehicle's magnetic field at sensor_1. When a vehicle enters the area of the sensor_2, then the timer_1 counting is stopped, the value of timer_1 is used to process the calculation speed. Next timer_1 utilized as controller "duration of anchoring" for sensor_2. Be seen that each of these timer's work "off" and "on" when entering and leaving area zero-offset. At the moment the vehicle has left sensor_1, timer_2 "timer_1" waiting on4 became "the last" on4 when vehicles have left the sensor_2. Empirical time total of timer_0 value is reduced by the value of the timer _ 2.

The table 1 shows maximum is the distance between the nearest vehicles that are following on some speed. If the distance is exceeded, then the vehicle's calculation to be wrong because it is considered the same/one.

Table 1. The maximum distance between the Nearest Vehicle

Vehicle Speed (km/h)	Maximum Distance to The Nearest (m)
5	2.0
10	2.7
20	4.1
30	5.5
40	6.9
50	8.2
60	9.6

3.2.3 Vehicle Classification

Classification of vehicles using the sensor HMC1001 has limitations, because the magnetic field is detected only from one area (Z-axis). So the writer must maximize the vehicle classification with its limitations. Vehicle classification, author of divide in 3 classes, namely class A (small car), class B (bus, truck 2-axis) and class C (> 3-axis).

The table 2 shows a division of the group's vehicles, along with the length of the vehicle. The table does not include all the length of the vehicle, since that became the focus of the calculation is the length of the vehicle was/is bordered by the other group. The length of the vehicle, was taken from the vehicle specifications catalog on the internet.

Table 2. Types of vehicles, length and group

No	Types	Length (mm)	Group
1	City car : Karimun	3340	**A**
2	Family car: Innova	4585	
3	Sedan	4531	
4	MPV	4890	
5	Truck 2-as	5800	**B1**
6	Truck 2 as (*dump Truck*)	5960	
7	Bus ¾	6980	
8	Truck 3 as(fuso)	8260	**C1**
9	Truck 3 as(fuso)	8557	
10	Truck 3 as(Box)	9200	
11	Truck 3 as(Box)	9800	
12	Standard Bus	12000	**B2**
13	3-as (trailer) >=14 meter	14000	**C2**

Based on observations of test data, then for the vehicle classification, the author did in 2 stages/levels, namely:

1. The classification based on the speed and the length of the vehicle
2. Classification based on the number of slope (hill pattern).

3.2.4 Classification based on the speed and the length of the vehicle

The early stages of the classification, the system will classify the vehicle based on the dimensions of the vehicle. The representation of long vehicles here was the duration or length of a vehicle that moves above a point (sensor). Based on data obtained from the tests, seen that there is a difference between empirical duration by mathematical duration. The biggest negative difference ±10.5% and the biggest positive difference ±25.8%. The percentage of the difference will be made as the limit of the tolerance range for vehicle classification based on the dimensions of the length of the car. To specify a percentage value tolerance limits group, if you are using the highest percentage difference in positive and negative difference, then it can cause a big enough slice area. Whereas the highest difference in frequencies is small enough. Therefore, the author will calculate in advance are generally descriptive statistics (mean/median/mode) to see the smallest error rate.

Then the calculation based on the analysis of the error, with the smallest presentation i.e. If the value 20% tolerance for difference in positive and negative difference 10%. Based on table 2 types of vehicles as well as the Division of the group, it will be determined in advance the limits range from each group corresponds to the magnitude of the difference between the value in the duration of the empirical. The calculation will only be done on the length of each vehicles between the group's different, so knowable existence of sliced between the two group.

1. MPV, length = 4890 mm, if the difference between maximum negatives on the empirical testing of 10%, then the toleration became 4890 4890 + (x 10%) = 5379 mm.

2. Car truck 2-axle, length = 5800 mm, if the difference between the maximum positive empirical testing on 20%, then the toleration became 5800 x 5800 (-20%) = 4640 mm. Because this value is smaller than the length of the MPV (4890 mm), then going with slices of group a. Then this value as well as the lower limit of the range "wedge" between group A and

group B1/upper limit of group a. and the upper limit of the range of sliced AB1 is 5379 mm.

So on with the same methods of calculation, it can look for the range values. Based on the division of the group as well as the calculation of tolerance limits between group-the group, then it can be made table 3.

Table 3. The division of the group based on long range

No	Group	Range (meter)
1	Group A	Group A <4,64
2	Group AB1	4,64 <=Group AB1<= 5,379
3	Group B1	5,379<Group B1 <6,85
4	Group B1C1	6,61<=Group B1C1<= 7,678
5	Group C1	7,678<Group C1< 9,6
6	Group C1B2	9,6<=Group C1B2<= 10.78
7	Group B2	10,78<Group B2 <=13,2
8	Group C2	13,2<Group C2

To calculate the time/duration of the moving vehicles are mathematically above the sensor, first created the equations using formula 1, this is to facilitate in this equation, because the programming that will be incorporated into the microcontroller.

If the length of the upper limit of group A is 4.64 metres, then the equation becomes:

$$t\ (ms) = \frac{X.3600}{V} \rightarrow t\ (ms) = \frac{16704}{V}$$

By using the same method, can be searched and the lower limit value upper limit for each user group. Based on these calculations, the table 4 shows a summary of the group's range of values.

Table 4. Division of range group based on time (millisecond)

No	Group	Range (*milisecond*)
1	Group A	*t (ms)* < 16704/V
2	Group AB1	16704V <= *t (ms)* <= 19364/V
3	Group B1	19364/V < *t (ms)* < 23788/V
4	Group B1C1	23788/V <= *t (ms)* <= 27641/V
5	Group C1	27641/V < *t (ms)* < 34560/V
6	Group C1B2	34560/V <= *t (ms)* <= 36432/V
7	Group B2	36432/V < *t (ms)* <= 47520/V
8	Group C2	47520/V < *t (ms)*

The above equations, tables as the basis of making the decision tree for classification of the vehicle. So in the first stage of classification, "If there is a vehicle that came in at speed V km/h, then the microcontroller will calculate mathematically all t (ms) each incorporate the range with the value of the velocity V is detected on all of the above equation. After the calculation of the duration of the obtained mathematical, then compared with the empirical duration were detected, so that the system can group or classify the detected vehicles are on a particular group ".

The author has conducted testing on the program above, to classify the vehicle on the city car, family car, and sedan are ± 6 attempts respectively. At different speeds (at random), and its gives good results, i.e., a number remain in group a. Group AB1 group B1C1 C1B2 and group, is a group that needs to be separated slices again using parameter-another parameter.

3.2.5 Classification Based on The Number of Hill Pattern

The second stage in the classification of the vehicle is a vehicle that is on a separate area sliced AB1, B1C1 and C1B2. Based on the results of sampling of vehicles, sedan cars has the largest amplitude value, this is because the car is quite low (closer to the sensor), so magnet field that read strong enough. On trucks and buses, has an average of smaller amplitude. Although the vehicle is great, but because it has a fairly high dimensions from the road (sensors), so magnet field unreadable small also. Thus, the largest amplitude parameters, amplitude average and peak to peak, cannot be used to classify the vehicle. So the parameters that will be used in the second stage of calcification is "average number of slope/hill pattern", due to the differences in value enough to classify each user group.

Based on the data and table 4 number of hills pattern then can be made a decision tree to do the classification of the vehicle as figure 12.

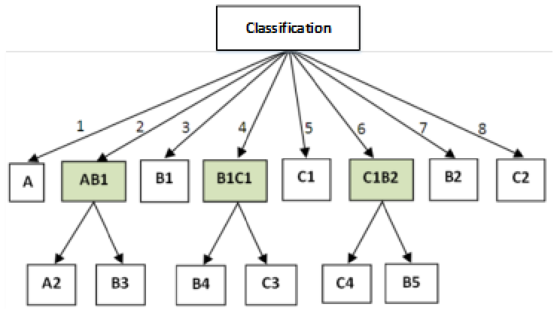

Figure 12. Decision tree classification of vehicles

IV. CONCLUSION

After doing a series of testing and analysis, some conclusions can be drawn so that the magnitude of amplitude magnetism posed a great small vehicle depending on the vehicle and also the distance/high low vehicles from the sensor. Magnetic sensor HMC 1001, giving good results to be used as vehicle speed detection and counting the number of vehicles, both at low speeds as well as high. Presentation error classification of vehicles based on the length and speed of the vehicle, relative between +5% s/d +10%. However, these classifications will still produce some group slices, the slices so that the group will be separated again based on the amount of hill pattern. Where his percentage error +36,4%. This vehicle classification system, still has a weakness that is not able to classify vehicles that stop above the sensor, this is caused by the phase 1 classification is dependent on the length and speed of the vehicle. Sending data

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