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Detection of the Vehicle Direction with Adaptive Threshold Algorithm Using Magnetic Sensor Nodes

Araştırma Makalesi / Research Article

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ABSTRACT

In this paper, we describe how, so as to perform vehicles direction detection in road traffic using proposed method along with the average-constant threshold and contributions of adaptive threshold detection algorithm (ATDA) thanks to special-purpose sensor nodes integrated with magnetic sensors. In this study, proposed algorithm with the adaptive threshold value as a magnetic resultant force has produced more pronounced and precise results than the average-fix threshold value. In this mean, it is clear that detected adaptive threshold generates more correct result for the systems like vehicle existence, direction assignment, and speed detection in different grounds where magnetic field is changeable as a result of environmental measurements. The direction of motion of the vehicles on the x-axis was determined as well as whether it was from left to right or from right to left, and the results were 97% average accurate. The simplicity of the proposed algorithms, the absence of any complex computations, the low cost of the sensor node and integration and the low power depletetion of the communication system show the avantage of this system in comparison with the other studies.

Keywords: Wireless sensor networks, magnetic sensor, adaptive threshold detection algorithm (ATDA), vehicle direction detection.

ÖZ

Bu çalışmada, manyetik algılayıcılarla entegre özel amaçlı sensör düğümleri sayesinde, ortalama sabit eşik ve adaptif eşik algılama algoritmasının (ATDA) katkılarıyla birlikte, önerilen yöntem kullanılarak trafik yollarında araç yönü algılamasının nasıl yapılacağı anlatılmaktadır. Bu çalışmada uyarlanabilir eşik değeri manyetik sonuç kuvveti olarak önerilen algoritma, ortalama düzeltme eşiği değerinden daha belirgin ve kesin sonuçlar vermiştir. Bu anlamda, tespit edilen uyarlanabilir eşik, çevresel ölçümler sonucunda manyetik alanın değiştirilebildiği farklı gerekçelerdeki araç varlığı, yön tahsisi ve hız tespiti gibi sistemler için daha doğru sonuç ürettiği açıktır. Araçların x-ekseni üzerindeki hareket yönü, soldan sağa mı yoksa soldan sağa mı doğru belirlendi ve sonuçların ortalaması% 97 çıkmıştır. Önerilen algoritmaların basitliği, herhangi bir karmaşık hesaplamanın olmaması, sensör düğümünün düşük maliyeti ve entegrasyon ve iletişim sisteminin düşük güç tükenmesi diğer çalışmalara kıyasla bu sistemin avantajını göstermektedir.

Anahtar Kelimeler: Kablosuz algılayıcı ağlar, manyetik sensör, adaptif eşik algılama algoritması (AEAA), araç yönü algılama

1. INTRODUCTION

Wireless sensor networks (WSNs) are a developing technology and has great potential to be employed in critical situations [1]. The key advantage of WSNs is that the network can be deployed easily and can operate unattended, without the need for any pre-existing infrastructure and with little maintenance [2]. Figure 1 presents a WSN architecture.The sensor is also referred to as the detector or probe, as well as the elements that perform the sensing process in electronic applications.

The main components of the sensor node are the microcontroller, transceiver, power supply, memory, and one or more sensor components. There are many types of nodes used in the market to create wireless sensor networks, such as TelosA,TelosB, Mica2, MicaZ, eMote, IMote2, and Sensenode [3-5]. Which direction of the vehicles moving towards in the traffic, is important in terms of traffic safety and management. It is possible drivers and traffic officers to obtain direction information of the vehicles and to provide traffic coordination, which can significantly reduce traffic accidents. So, in this study, the direction of vehicles in traffic, was determined by means of magnetic sensor. In this work, sensor nodes capable of working in a number of convenient ways have been used and installed sensor sensors using magnetic sensors (HMC5983L) placed on them. These sensor nodes used are less costly than market nodes such as TelosB or MicaZ. With the help of these sensor circuits, the direction of any vehicle passing by is firstly determined by the fixed threshold value and then by the adaptive threshold value detection algorithm. In this study, adaptive threshold detection algorithm is used unlike other study. This demonstrates the our contribution of the paper. Direction of vehicles is detected using both fixed and adaptive threshold algorithm, were compared the results of the algorithms with each other. It has been obtained nearly 100 % accuracy rate with adaptive threshold algorithm. The use of the sensor node optimally and a precise threshold algorithm shows the superiority of this work. Furthermore, the use of sensor nodes and proposed energy efficient algorithm clearly demonstrates the diffrence from other studies and the novelty of this study.

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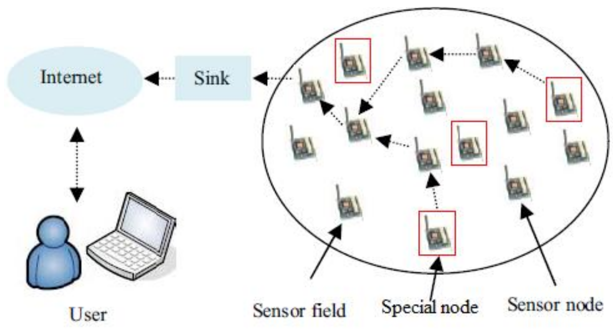


Figure 1. A WSN architecture

The rest of the paper can be listed as follows. Section 2 shows the previous work on the subject. In section 3, the system concept is explained in detail by explaining the concept of magnetic sensors and the scenario considered. The adaptive threshold value algorithm is described in section 4. Experimental results and system analysis are presented in section 5. Finally, the results of this study and the proposals on the study are discussed in section 6.

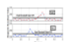
2. RELATED WORK

In many studies, on behalf of detection, finding direction, speed, recognition of the vehicles, sensor node systems have been developed. Anisotropic magnetoresistive sensor (AMR) and microphone sensor were used to investigate the vehicles road direction detection and traffic situation of any road [6]. In addition, a wireless sensor with a magnetometer sensor was used using an acoustic sensor [7], an ultrasonic sensor [8], and video camera analysis systems or ariel images [9]. The detected magnetic field over a certain threshold value was measured on the time axis as a signal, Vehicle detection and various applications like monitoring parking system of the vehicle or vehicles moving on the roads have been developed [10]. Another study examined a real-time traffic control system using wireless sensor networks [11]. In one study, traffic monitoring system was proposed as a system integrated with mobile data monitoring and management [12]. Wireless sensor networks have been used to detect vehicles using multiple sensors, and vehicles are classified as light, medium and heavy vehicles [13]. An optimal partitioned sample-based classification and regression tree algorithm (CART) has been proposed to classify and find the direction of the vehicles on the road [14]. The motion artificial neural network method for mod-based vehicle recognition is proposed in [15]. The paper [16] presents an intelligent vehicle identification system used within a complete solution for a traffic monitoring system thatusesa novelwireless sensor network architecture to monitor traffic with vehicle direction detection. In a study, the system will estimate and track the target based on the spatial differences of the target signal strength detected by the sensors at different locations. Magnetic and acoustic sensors and the signals captured by these sensors are of present interest in the study. The system is made up of three components for detecting and tracking the moving objects [17].The paper [18] resaerchs monitoring free flow traffic using vehicular networks and vehicle types and directions. In another paper [19], authors survey recent progress in mobile WSNs and compare works in this field in terms of their models and mobility management methodologies. In a research paper [20] proposes an algorithm which not only determines green light duration dynamically but also handles the emergency vehicle management efficiently. It also handles the deadlock and starvation condition, which causes due arrival of emergency vehicle in repeated interval of time in traffic intersection. The paper presents a way to build a strong, secured wireless network in vehicle. The proposed method of encryption and decryption ensures that, sensor and actuator data is available only to required ECUs and not to any other unintended receiver [21].

3. PROPOSED ALGORITHM AND SYSTEM DESIGN

The main purpose of using magnetic sensors is not only to measure the magnetic field. There are many purposes such as detecting the vehicle, determining the type of the vehicle, determining the direction of the vehicle, finding the speed of the vehicle or detecting the presence of magnetic change. Direct measurements can not be made to achieve these goals or the correct result can not be reached with certain parameters. Conventional sensors such as temperature, pressure, light and voltage can convert the desired parameter directly into proportional voltage or current output. However, magnetic sensors can not directly detect direction, angle or electrical currents. First of all, the magnetic field that occurs or changes with the applied input becomes the subject matter. The current or iron derivative object in the copper wire causes a change in the magnetic field of the place. When the magnetic sensor senses magnetic field changes, it needs to pass through the signal processing process in order to convert the output signal to the desired parameter value. This process is a step that makes it difficult to use the magnetic sensor in many applications. However, a good understanding of the effects of these changes facilitates accurate and reliable results [10, 22].

There are many sensor types produced by Honeywell used in the market. HMC1001, 1002, 2003, 5983L are just a few of them. They are separated from each other by single, double or triple axis measurements.

We have used HMC5983L magnetic sensor in this sudy as seen in Figure 2. The main reason for using this sensor in this work is that it can be connected to the sensor node via  port and communicate in serial via pins.

M_X, M_Y and M_Z represent the magnetic force for each of the 3 axes is obtained by converting the 1-byte magnetic value in each X, Y, and Z data registers to the value in the decimal value,respectively. As a result, the resultant value (C_{RV}) is calculated with the help of equation 1.

$$C_{RV}=\sqrt{{M_X}^2+{M_Y}^2+{M_Z}^2} \quad (1)$$

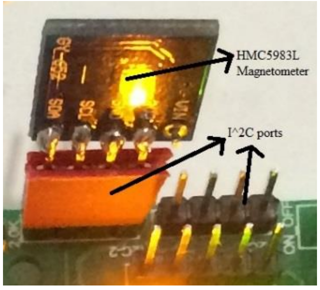


Figure 2. HMC5983L Magnetic Sensor

This C_{RV} value corresponds to the magnetic data a(t) when adaptive threshold detection is performed. When the vehicle approaches the nodes, the value of C_{RV} rises. Because the vehicles abundantly contain metals such as iron, nickel or cobalt (ferrous mass) and change the ferromagnetic wave of the place [23]. Normally, the magnetic field of the place is about 500 mGauss and this value increases or descreases when the vehicle magnetic sensor passes near 0.5-0.75 m. If this C_{RV} value is divided by 256, the gaussian magnetic field value is computed. For example, if the C_{RV} value is 276, the magnetic field at that location means about 1.07 gauss. The magnetic change in all three axes causes the C_{RV} value to change. When the vehicle is detected with the HMC5983L magnetometer, the C_{RV} value is basically measured. If any road passes near this sensor circuit, which is placed on the side or center of the vehicle, the value of C_{RV} is measured above the predetermined threshold ($C_{threshold}$) and means there is a vehicle on the way. So the vehicle is detected.

A professional sensor circuit, which is used for vehicle direction detection systems during this operation, is shown in Figure 3 with its power card and battery connection. This sensor node's name is WİSeN and sold on the [24]. This node differs from other sensor nodes such as TelosB, MicaZ by the optional creation of hardware components.

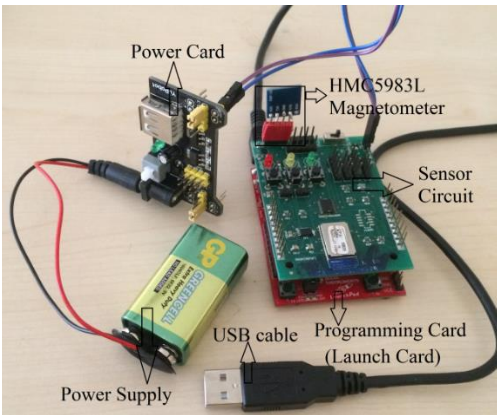


Figure 3. Sensor circuit designed for vehicle direction detection

On this sensor node, there are many connectors for convenience of SHT11 temperature, humidity sensor, EEPROM and operation. In addition, there is a UART1 connector to which the Sim900 node can be connected and a UART2 connector to which the serial port output can be monitored, which is used to transfer the data obtained by the sensor to the internet environment [25-27].

As can be seen from Figure 3, the HMC5983L (magnetic sensor) sensor, which is directly attached to the I^2C port of the sensor node, can be used as a 3-axis compass. When the sensor circuit is designed, the 3.3 volt output of the power board is connected to the Vcc pin of the sensor circuit. With a 12-bit ADC, the angle with respect to the magnetic poles of the earth can be found with 1-2 ° accuracy.

In addition, when a metal object is brought close to the compass sensors and the sensor nodes communicate over the I^2C protocol. When the sensors are programmed, the values of all the axes of the sensor are read, and the resultant value (C_{RV}) is calculated by the formula in equation 1. If the sensor is not used as a compass but only the magnetometer is influenced by other objects, the resultant value is sufficient. Here, the resultant value is different in each environment, but the value changes when a metal object is approximated. In this way, the metal objects around the sensor can be understood.

In this study, firstly, it was determined based on the magnitude of the magnetic wave and the duration of the vehicle's proximity to the sensor node. Secondly, the adaptive threshold value algorithm is applied to the proposed system to determine the direction of the vehicles.

In the first application, a fixed threshold value [27] based on a threshold value assumption is based on a very small average of the threshold values obtained in experiments on 100 vehicles.

In order to make vehicle detections and to make more precise and accurate measurements, one wireless sensor node is placed in the middle of the road. In this study, the magnetic information and the magnetic resultant force (C_{RV}) value are found using equation 1. The magnetic sensor is connected to the I^2C port of the sensor node. If the sensor circuit is thought of as an end node, it will send the programmed node as a magnetic data pick-up node. The end node, the magnetic information of the 3 axes (x, y, z), is created by the software that generates the magnetic junction and transmits this value every 90 ms to the collector node (coordinator node). That is, the coordinator node sends a C_{RV} value to the Tera Term, serial port software, each 90 ms. $C_{threshold}$, which is a constant threshold value in the study implemented, was initially set at 253. However, this value may be different in different environments because of being different magnetic field values in different parts of the world. After many experimental applications for vehicle detection, this $C_{threshold}$ value is set to 255 for the fixed threshold algorithm. Values below this value are considered "no vehicle" and values above are considered "vehicle". For this reason, the magnetic sensor used may be influenced by other metals in the environment during the measurement. However, by using the adaptive threshold value detection algorithm, the adaptive threshold value h(k) is determined and vehicle orientation is determined based on this level. Also, using the adaptif threshold level, we avoided the measuremental complexity for each environment, so we found the threshold value dynamically. The magnetic sensor HMC5983L transfers the data acquisition node received every 90ms. Reduction of this means that the number of samples of magnetic data will increase. Although the increase in the number of samples gives more clear and precise results, Tera Term can not obtain data in a very short time. For this reason, the sampling time is set to 90 ms as the optimum time.

In this study, the direction of motion of the vehicles was determined by passing. The direction of the vehicle is from left to right or from right to left. In this application, more than one sensor was used and the change in the magnetic field was measured in the direction of motion in one direction. Figure 4 gives the application scenario for the vehicle direction determination.

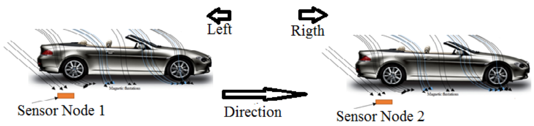


Figure 4. Direction determination scenario

In this study, to detect the direction of the vehicle, two sensor circuits were placed in the middle of the road 8 m apart. The aim here is to observe if the change in magnetic field was similar in the nodes placed nearby. The direction is determined when the resultant magnetic field C_{RV} in one of the nodes exceeds the $C_{threshold}$ at a certain time before the other node detects the vehicle. As in the previous application, the measurement time interval of the sensors was set to 90 ms. Figure 5 shows the flow diagram of the algorithm to determine the vehicle direction.

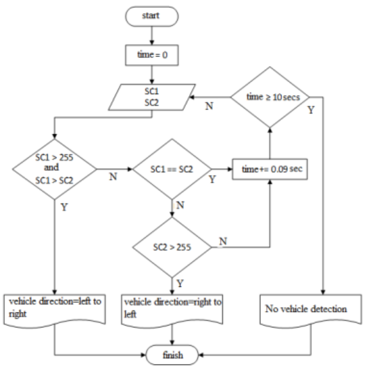


Figure 5. The flow chart of the proposed algorithm to detect the vehicle direction

SC1 and SC2 arguments in the flow chart are the C_{RV} values read at the sensor 1 and sensor 2, respectively. To implement this application, firstly, a car was made to pass by the sensor nodes at a fix speed of 45 mph as in Figure 6. The direction on the x-axis is decribed as from left to right if the car travels from sensor 1 to sensor 2 and from right to left otherwise. Magnetic signature length (MSL) value used in vehicle direction determination is computed with the multiplying of the magnetic amplitude difference (ΔM) and the occupation time (Δt) vehicle in the sensor node range. However, magnetic signature length value is calculated as $MSL = \Delta Mx\Delta txV$ if vehicle speed (V) is taken into consideration. In this way, when a vehicle pass by the road at a speed faster than previous, Δt decreases and MSL remains constant. Similarly, when a vehicle passes by the road at a speed slower than previous, Δt increases and MSL remains constant. To put it more clearly, ΔtxV expression in the $MSL = \Delta Mx\Delta txV$ equation describes D_V which is distance path received by the vehicle in the sensor node' coverage area. So, we consider the magnetic signature length value as $MSL = \Delta Mx\ D_V$. In this sense, MSL does not vary if the vehicle's speed is changeable. In this study, magnetic signature length value is used as $MSL = \Delta Mx\Delta t$ because of the fact that speeds of the vehicles are constant. This means that we assume Δt value is equal to D_V.

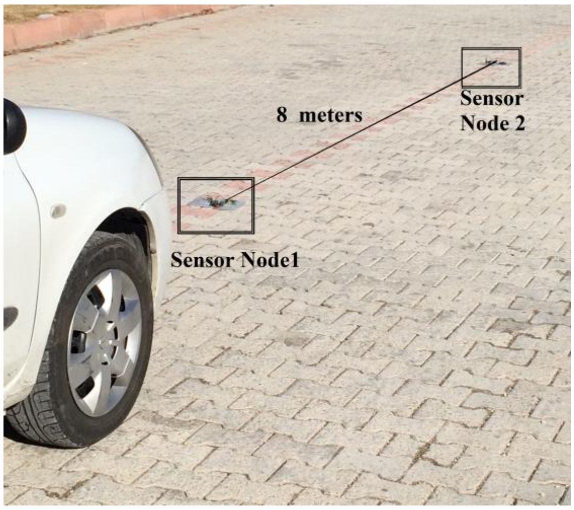


Figure 6. The vehicle approaching the sensor circuit

Hovewer, uncertainty condition related to vehicle direction can occur like Figure 7 below when vehicle presence is detected by the two sensor nodes. So, it can not be understood that V_1 and V_2 vehicles are moving in which direction according to Figure 5. However, which vehicle in which direction to move can be determined by acquiring magnetic measurements and plotting related signal graphics.

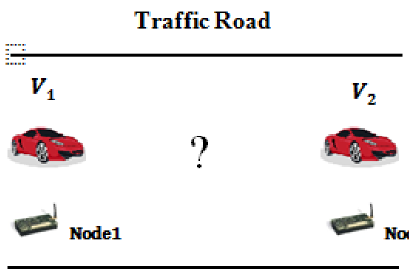


Figure 7. Uncertainty of the direction of the vehicles

For instance, when obtained graphic as seen Figure 8 below to be seen V_1 vehicle passed over the Sensor node 1 in the t_2 - t_3 time interval at first and Sensor node 2 in the t_5 - t_6 time interval later, it can be understood that the direction of the V_1 vehicle was determined as from left to right according to Figure 5. Similarly, as seen Figure 8 to be seen V_2 vehicle passed over the Sensor node 2 in the t_0 - t_1 time interval at first and Sensor node 1 in the t_4 - t_7 time interval later, it can be understood that the direction of the V_2 vehicle was determined as from right to left according to Figure 5. Also, vehicle presence was detected by the two sensor nodes in the t_5 - t_6 time interval according to Figure 8. However, it is obvious that obtained magnetic signal gives different results for different vehicles. In this mean, it is easy to decide which vehicle in which direction to move on the road.

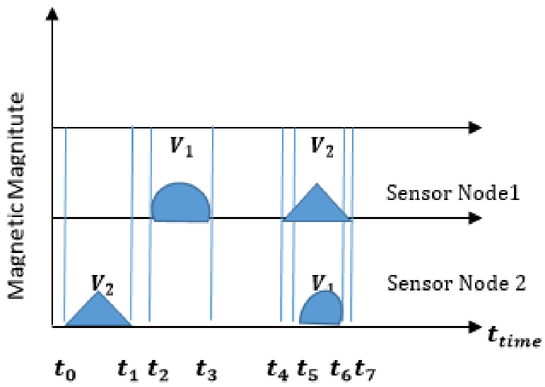


Figure 8. Determining the direction of the vehicles

4. ADAPTIVE THRESHOLD DETECTION ALGORITHM

The necessity of the large-scale use of traffic surveillance systems necessitates a strong and accurate design of vehicle detection algorithms. Adaptive threshold detection algorithm (ATDA) was proposed by Cheung and Varaiya in 2007 [27] to detect vehicles in traffic based on magnetic signals in this mean. With this algorithm, it is aimed to determine the threshold value on the magnetic signal taken from the sensor nodes and to present a suitable solution to the vehicle detection decision. In order to produce real-time detection results, to reduce the calculation requirement of the detection algorithm and to consume less energy in the processor of the sensor node, other static algorithms or assumptions are replaced by threshold value logic. Figure 9 shows the block diagram of the adaptive threshold detection algorithm [25,26].

The signal from the node is filtered to convert the corrected signal to the shape. The signal is used when the signal has an adaptive edge line. After the edge line is detected, a magnetic signal is sent to the detection status machine. Then, a detection flag is generated by means of the output state buffer.

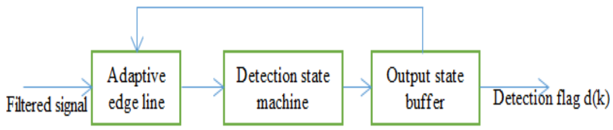


Figure 9. Block diagram of adaptive threshold detection algorithm

4.1. Adaptive Edge Line

Although there is an uncontrollable deviation in the magnetic signal, the rate of deviation is very low because it is often measured. This means that if the signal of the moving vehicle is 1 second during the process, the signal deviation of the vehicle detection has negligible effect. An adaptive edge line must be watched and generated in a magnetic readout so that the long-term lead can be calculated. In this case, an adaptive threshold value level can be determined for the detection state machine. The adaptive edge line for all three magnetic axes is found by means of equation 2 [25,27].

$$B_i(k) = \begin{cases} B_i(k-1)x\,(1-\alpha_i) + a_i(k)x(\alpha_i) \\ \quad if\ \ s(\tau) = 0\ \forall\, \tau \in \left[\left(k - s_{buf}\right) \dots .(k-1)\right] \\ \qquad\qquad\qquad for\ i\ \in\ [x\ y\ z] \\ B_i(k-1) \qquad\qquad otherwise \end{cases} \tag{2}$$

$$T(k) \begin{cases} \left.\begin{cases} true\ \ if\ |a_z(k) - B_z(k)| > h_z(k) \\ false \qquad otherwise \end{cases}\right\} for\ s(k-1) \neq Event_{detect} \\ \quad \left\{\begin{matrix} true\ \ if\ |a_z(k) - B_z(k)| > h_z(k)\ \ or \\ true\ if\ |a_y(k) - B_y(k)| > h_y(k)\ or \\ true\ if\ |a_x(k) - B_x(k)| > h_x(k) \end{matrix}\right\} \\ false \qquad otherwise \qquad for\ s(k-1) \neq Event_{detect} \end{cases} \tag{3}$$

B(k), adaptive edge line, *s (k)*, the detection state of machine state, α forgetting factor, s_{buf} ,the buffer size of *s(k)*, *h(k)*, the threshold value level, *a (k)*, filtered magnetic data and finally *i*, represents every three axes. With these equations, the adaptive edge line is updated by magnetic reading only when vehicle detection is not performed for a certain period and when there are no signal fluctuations. With this adaptive edge line, the "Over_threshold" flag is generated according to equation 3.

In the case of two different vehicles standing and moving near the sensor node as seen in the studies performed, it is not possible to get a false result below the threshold and to take into account the measurements on the X and Y axes as well as the Z axis for the decision state of *T(k)* when the state machine is in the "Event_detect" state is as taken.

4.1. Detection State Machine

The "Over_threshold" flag state machine is used to filter out the artifacts that occurred before vehicle detection. The state machine consists of 5 main cases [25].

• S1: "Start_edge line"

This is the state that is used to generate a reset state when there is no vehicle near the sensor node. In this case, the edge line will be started by going to S1 and by environmental measurements.

• S2: "On_edge line"

After the predetermined time has elapsed, the edge line branches to S2 state where it is adaptively updated. The measurement on the Z axis is branched to the state S3 if it is greater than the adaptive threshold.

• S3: "Over_threshold_counter "

This state counts when *T (k)* is true. In cases where *T(k)* is false, it branches to S4. Otherwise, it branches to S5 when reaching a certain number that *T (k)* is true.

• S4: " Below_threshold_counter "

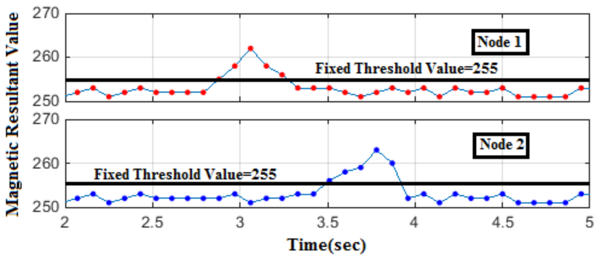
In this case, when the number of *T(k)* is false reaches a certain number, it branches to S2. When *T(k)* is true to avoid miss the vehicle detection, it branches to S3 state.

• S5: "Event_detect"

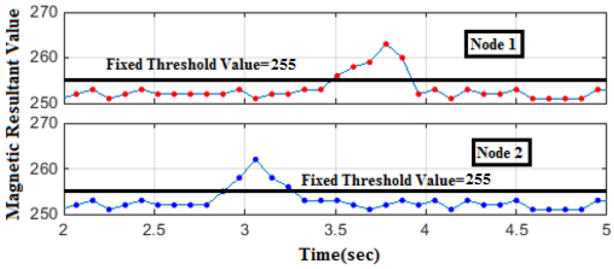
This means that magnetic fluctuations are moving near the sensor node of the vehicle. It is read from the sensor nodes that all three axes *T(k)* are true. After the vehicle has been detected, *T(k)* goes false and branches to state S2 when the false state reaches a certain number. When the detection period arrives at the specified period, the state machine branches back to S1 to start these operations again. After detection, the detection flag *d(k)* generates the output status [26].

5. EXPERIMENTAL RESULTS

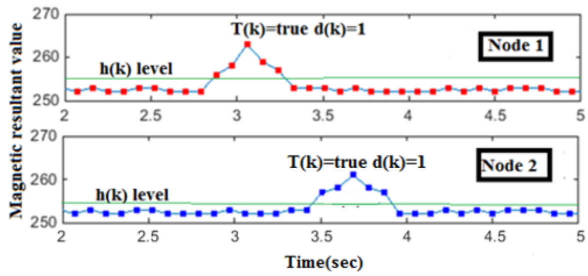
Firstly, we implemented on fixed threshold algorithm and are shown in Figure 10.a. According to Figure 10.a, the vehicle was detected first by Node 1 and then by Node 2. Node 1 reported the precense of the vehicle in a locating where measurements were taken every 0.09 s. Soon after, Node 2 also imformed the vehicle precense. Hence, for short period of time, Node 1 sends the logic value 1 and Node 2 sends the logic 0. Then, Node 1 sends the logic 0 and Node 2 sends the logic 1.



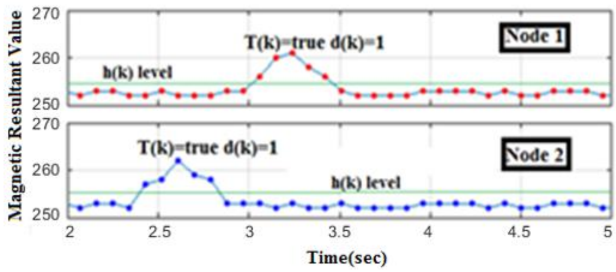
a) Detection of the vehicle direction, from left to right (Fixed threshold algorithm)



b) Detection of the vehicle direction, from right to left (Fixed threshold algorithm)



c) Detection of the vehicle direction, from left to right (Adaptive threshold algorithm)



d) Detection of the vehicle direction, from right to left (Adaptive threshold algorithm)

Figure 10. Experimental results according to the algorithms

These results were plotted with Matlab program. Because a flow from Node 1 to sensor Node 2 was seen, the direction of the vehicle was determined as from left to right. However, It can be understood that the vehicle was first detected by sensor node 2 and then sensor node 1 and therefore it is determined that the vehicle was moving from right to left as seen in Figure 10.b. Secondly, we conducted the proposed algorithm with adaptive threshold manner and shown in Figure 10.c. According to equation 4, $T(k)$ was found "true" due to the fact that threshold level was exceeded. Also, *d(k)* output flag was determined logical 1 (Figure 10.c). Threshold level *h(k)* could be seen in Figure 10.c. So, the vehicle was detected first by Node 1 and then by Node 2. For example, the highest magnetic resultant value detected by Node 1 was 264 and by Node 2 was 263. The occupation times in the coverage zone of the sensor were

Table 1. Accuracies for the algorithms of vehicle direction determination

Algorithms	Direction of Vehicle	The number of vehicle passed	The number of vehicle detected		Accuracy of the algorithms
			Left to right	Right to left	
[6]	Left to right	50	47	3	%94
	Right to left	50	3	47	%94
CART	Left to right	50	47	3	%94
	Right to left	50	2	48	%96
Fixed Threshold [27]	Left to right	50	48	2	%96
	Right to left	50	2	48	%96
Proposed With Adaptive Threshold	Left to right	50	49	1	**%98**
	Right to left	50	2	48	**%96**
Total number of vehicle for each algorithm 100					

also similar. Because a flow from Node 1 to sensor Node 2 was seen, the direction of the vehicle was determined as from left to right. In addition to these, data obtained by the sensor were similar with each other. So, one could understand that the same vehicle passed by the nodes. The plot showing the vehicles moving from right to left is given in Figure 10.d. It can be understood that the vehicle was first detected by sensor node 2 and then sensor node 1 and therefore it is determined that the vehicle was moving from right to left. As a results of this simulations, we obtained more precision and accurate threshold value in adaptive threshold algorithm than the fixed threshold algorithm. After that, a direction determination experiment was performed with 100 vehicles of which 50 were travelling from left to right and 50 were travelling from right to left. In this way, the study in reference [6], Classification and Regression Tree (CART), fixed and proposed adaptive threshold detection algorithms were compared in terms of direction determination criterion. As seen in Table 1, an accuracy of 98% was attained for vehicles moving from left to right and 96% for the ones moving from right to left when used the adaptive threshold detection algorithm. In general, the system has an accuracy of 97% which is the highest rate among the all algorithms.

6. CONCLUSIONS

In this study, as a new approach fixed threshold value detection and adaptive threshold detection algorithm are compared by using the purpose-specific wireless magnetic sensors. In this view, the results of the two methods are analyzed and the importance of the adaptive method, which may be more suitable for use in vehicle direction finding systems, is emphasized. In this method, the necessary parameters are given as inputs and the vehicle recognition system is provided with the flag based on the output buffer. The adaptive threshold level is dynamically determined and a level below the default constant threshold value is obtained. In addition, this method allows for accurate results to be obtained adaptively in different environments as different parts of the world have different magnitudes of magnetic fields.

The most important features of this work are that the vehicle detection system is simple, relatively dynamic with other operations, and that the proposed method and algorithms produce appropriate results. In addition, the amount of equipment used and the low cost of the materials used reflect the other feature of trying to communicate the sensor nodes according to the Zigbee communication standard, which consumes low power with each other.

In future studies, various parameters such as mass, types, speed and size of vehicles, will be analyzed and contributed to the traffic monitoring applications. In addition,, researchers can offer more performance solutions making energy efficient evaluations of acquired vehicle information.

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