Internet of Things Based Free Parking Space Management System

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***Abstract*—Internet of things is an emerging technology that enables every object of our surroundings to be connected and controlled from a distance. Wireless sensors can be integrated to the internet and the sensor data can be monitored and thus detect events from distance. Reliable free parking-space management system is important to maintain the discipline and better utilization of the parking space. Free parking-space management system using wireless sensor networks is less expensive and requires less installation requirements. In this paper, we have illustrated a complete implementation of free parking-space management system using wireless sensor networks. We have used sensor motes of Texas Instruments each consisting of ten sensors. We have employed four sensors, magnetic, light, temperature, and ambient temperature sensors of the motes for reliable detection of the free space. We have optimized the operating system, adopted low-powered efficient networking protocol and a lightweight messaging model for data transmission. We have implemented the system and deployed in a parking area. Our experimental results show that the system can detect vehicle presence with an accuracy of 98%.**

I. Introduction

The internet of things (IoT) is the network of objects surrounding us that are embedded with electronics. The connected objects can collect and exchange data over the internet and thus can be controlled from a distance [1], [2]. The IoT enables us to monitor the objects remotely and efficiently take a decision. Wireless sensor networks (WSN) realize such a network that can sense several environment phenomenon of a location and can send the data to a distance [3]. WSN can be deployed to monitor free parking slot of a parking area with less cost than wired networks. Knowing the free parking spaces of a parking area from a distance enables the drivers to park the cars efficiently. Free parking space management system is widely studied area in the literature [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15].

The free parking space management system using hierarchical magnetic sensors has been illustrated in [11]. Each parking slot is equipped with three magnetic sensors and each parking area contains a sink node where the sensors report about the status of the slot. Each sink node sends the updated information through a gateway to a sever. A mobile app can get the parking information from the server. The usage of three magnetic sensors is redundant for such a system where there are many similar systems proposed using a single magnetic sensor per parking space [5]. Moreover, they have implemented this architecture in a simulation framework rather than real environment.

Free parking space management system using camera and image processing is illustrated in [4]. Parking spaces are partitioned and each partition is monitored by a camera. Live video footage of these cameras is processed and compared to empty space model to detect available car spaces. Such system is inherently expensive and required extensive installation requirement. Vehicle detection using magnetic and optical sensors is presented in [6], [5]. In this system, the optical sensor wakes up magnetic sensor optimizing sensor power usage. But only magnetic sensor is not sufficient enough to detect a vehicle. The amount of magnetic metal is not fixed in all vehicles. Moreover, if the chassis is higher and the amount of metal of the chassis is not much, the change in the magnetic sensor will not be sufficient. On the other hand, illumination level under a vehicle is not fixed. It becomes larger under such vehicle whose chassis is very high from the ground. Moreover, the magnetic sensor has x, y, z co-ordinates. The underlying assumption of the system is that the z axis of the magnetic sensor is always vertical to other two axes. But in real deployment, the z axis of the sensor may tilt changing the status of vehicle detection.

In this paper, we proposed a parking-space management system consisting of four sensors: a magnetic sensor, a light sensor, an object temperature sensor and an ambient temperature sensor. To overcome the limitation of magnetic and light sensors we have used two temperature sensors to increase reliability of the system. We proposed a technique that resolve tilting placement of magnetic sensors. We have proposed a solution to the problem of light sensor for varying illumination level under the chassis. We have implemented the proposed system using the cc2650stk [16] sensor mote, a Texas Instrument consisting of ten sensors. We have ported the magnetic sensor driver for the Contiki operating system [17] of the mote. We have adopted the 6lowpan [18] as the network layer protocol that has IPv6 stack to enable the system as an Internet of Things (IoT). We have adopted the MQTT [19] as message passing protocol which is an ideal protocol for IoT. We proposed an algorithm to find the free space of the parking area. We have installed our system on a parking space and observed that our system successfully detects all the vehicles. We summarize the contributions as follows:

- We proposed a reliable parking-space management sys-

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tem using four sensors: a magnetic sensor, a light sensor, an object temperature sensor and an ambient temperature sensor.
- We proposed a new technique to overcome the magnetic sensor placement problem.
- We proposed a technique to overcome the illumination problem under the chassis of the vehicles for the light sensor.
- We have implemented our system such that the system can work as an Internet of Things and can transfer real time data for quick detection of vehicle presence.
- We have installed the system in a parking space and observed that our system works perfectly well.

The rest of the paper is organised as follows: Section II illustrates the architecture of the proposed system, Section III presents the technical details of the system, Section IV explains the algorithms that detects the vehicle presence from the data observed by the sensors, Section V explains the implementation details and analyzes experimental results, and finally Section VI concludes the paper.

II. Proposed system architecture

In this system each parking space is equipped with a sensor node on the bottom position of the space as shown in Figure 1. The sensor node has four sensors: a magnetic sensor, a light sensor, an object temperature sensor and an ambient temperature sensor. There is an access point also known as border router in the system where the sensor nodes can send information.

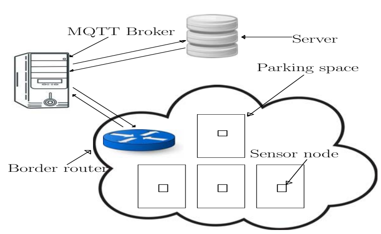


Figure 1: The overview of the IoT based parking space management system.

Every sensor node determines whether there is a vehicle over it based on sensor data. We propose an algorithm through which the sensor nodes determine the status of the parking space. The algorithms are explained in Section IV. The sensor node sends the information immediately to border router. Sensor node stores data to global database through border router. The border router sends the information to MQTT broker. Server collects information from the MQTT. The web based software presents the available or occupied status of the parking spaces.

The information provided by the web based application helps the drivers to park their cars more quickly than otherwise necessary in absence of that application. Without such application the driver needs to check every space and tries to find a free space. This task becomes tedious for a driver in particular in a large parking area when the available parking spaces are small compared to the total spaces of the area.

III. Vehicle detection technique

For vehicle detection choosing of sensors depends on the physical phenomenon of a vehicle. In this paper, we consider three phenomena: first, almost all vehicles are made of metal; second, there will be shadow beneath the vehicle when the space is not dark; and third, when a vehicle runs it generates heat. Almost all vehicles are built of metal. Since almost all vehicles have significant amounts of ferrous metals in their chassis (iron, steel, nickel, cobalt, etc.), the magnetic field disturbance created by a vehicle is sufficient to be detected by a magnetic sensor, which makes it a good candidate for detecting vehicle presence [20]. If the place is not dark there will be a shadow beneath the vehicle. If a vehicle comes over a light-sensor node the reading of the light sensor is changed. Hence, we used a light sensor for vehicle detection.

When a vehicle runs or just stop running its temperature is higher, and the temperature under the vehicle becomes higher too. We used object temperature sensor to detect the temperature of the vehicle. But we have observed that ambient temperature sensor provides useful data which can be used along with object temperature sensor for precise detection. Hence, we used object temperature sensor and ambient temperature sensor in our system. Note that ambient temperature sensor detects the surrounding temperature. Although magnetic and light sensors are used for vehicle detection there are some issues in real deployment which need to overcome for accurate detection of vehicle presence.

In the ideal position of the magnetic sensor, the z-axis of the magnetic sensor is always vertical to the horizontal line of the earth. Hence, all changes of magnetic sensor due to vehicle presence are experienced along z axis only. But such an ideal installation of magnetic sensor in real environment is impractical. In real deployment, sensor nodes may be tilted from ideal position during installation and their axes co-ordination may change. In this paper, we have proposed technique to avoid the tilt problem. Instead of considering only the change along z-axis, we have considered the changes along other axes. Hence, we cannot use fixed threshold value as used in [6]. Rather, we proposed a calibration phase to determine a suitable threshold. Our algorithm first calibrates the magnetic sensor, and then determines a threshold depending on the real installation. We elaborate this technique in Section IV-A.

There is a significant gap between the illumination levels underneath the high and low vehicles. Because of the change of illumination level underneath the vehicle, the system may fail to detect the high vehicle. In this paper, we proposed an adaptive algorithm to handle the illumination problem. Our adaptive algorithm changes threshold depending on surroundings illumination level. The details of the algorithm is presented in Section IV-B.

Exact detection may not be possible for all types of vehicles. Rather, we propose a degree of correctness as shown in Table I.

Table I: Table Title

Room \ Date	A	B	C	D
Magnetic	Yes	Yes	Yes	Yes
Light	Yes	Yes	No	No
Object temperature	Yes	No	Yes	No

In this scheme, we set most preference to magnetic sensor as it is most immune to environmental noise and weather. Light sensor may give noisy data if there is dust, object temperature sensor gives noisy data if there is another object between the sensor and the vehicle. We propose classes A, B, C, D as the existence of vehicle in some degrees. Other combinations not shown in the table and are regarded as absence of vehicle. Class C and D are for the cases where the place is dark. From the experiments, we have observed that class B and class C are the most common classes to indicate presence of a vehicle.

IV. Vehicle detection algorithms

We proposed three algorithms for four types of sensors to detect vehicle presence. The three algorithms are combined to a single decision making algorithm. The first algorithm is for magnetic sensor, the second algorithm is for light sensor, and the third algorithm is for object temperature sensor and ambient temperature sensor. Finally three algorithms merge to determine the final decision. In each algorithm, we assume that initially there is no vehicle in the parking place.

A. Metal Detection Algorithm

Almost all vehicles have ferrous metal and the earth magnetic field is uniform over large area. If a vehicle comes over a magnetometer, the value of magnetometer will change. The flowchart of the algorithm detecting vehicle metal is shown in Figure 2.

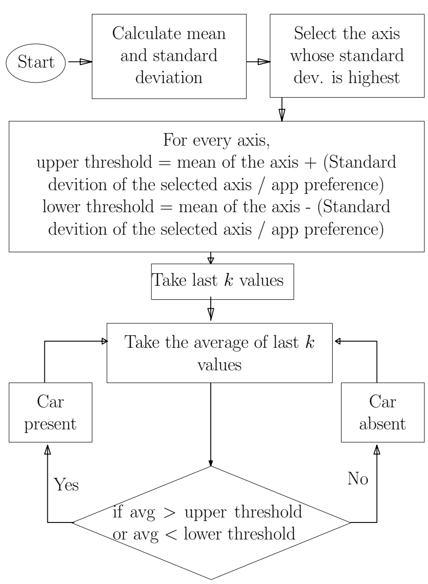


Figure 2: Flowchart for detecting vehicle metal.

First the algorithm calculates the mean and the standard deviation for all axes of the last k readings. As the orientation of the magnetometer may not be precise during installation, the magnetic effect due to vehicle presence may be experienced along any of the axes. To resolve this issue, as an initialization of the algorithm, we take a number of readings without vehicle presence in the space and determine the axis that has the highest standard deviation. The axes that has the highest standard deviation is the axis that will be experienced the change due to vehicle presence. We have used *lower threshold* and *upper threshold* to track the change of positive or negative direction of magnetic field depending on the direction of the vehicle movement. To determine the thresholds, we incorporate the error tolerance level by *app-preference* parameter. The app-preference is application specific and the value of app-preference sets the tolerance level of the system for accepting false positive or false negative decisions. If we choose app-preference higher it will increase false positive and vice versa. In our experiments we observed that when the vehicle is not present in the parking space, the distribution of magnetic sensor reading is normal distribution. For our experiments, the standard deviation and app-preference are within 3σ and correctly identified 99.7 % data where σ is the standard deviation. We determine the last k values of the last k readings and take the average of k values. Finally, to determine the status of car present status, we check the average value against the upper and lower threshold values as shown in Figure 2.

B. Shadow Detection Algorithm

We assume a light source is present in the parking space. Under the vehicle there is a shadow if there is any light source. But the amount of shadow is not fixed. It varies with light sources. The detection algorithm of vehicle shadow considers varying ambient light sources. And our observation reveals that the light intensity under the vehicle is almost half of the surroundings. But the surroundings light is not constant. It varies with light sources. Hence, we propose an adaptive algorithm to detect shadow under the vehicle. The flowchart of the algorithm is illustrated in Figure 3.

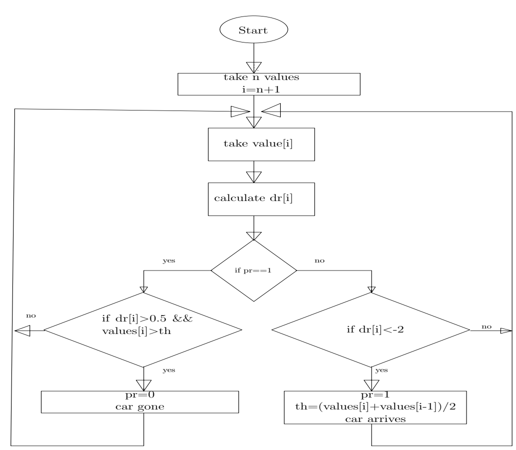


Figure 3: Flowchart for detecting shadow.

We assume that there are n initial light sensor data readings when there is no vehicle present in the parking space. In this algorithm, the *pr* stores the status of vehicle presence where its value 1 indicates a vehicle is present on the parking space and its value 0 indicates a vehicle is not present on the parking space. After getting i^{th} value $dr[i]$ is calculated. The $dr[i]$ is the difference rate of previous light sensor value with respect to i^{th} value(see Figure 4). It measures the change of light sensor data over time.The calculation $dr[i]$ depends on the previous k values of light sensor as shown in Figure 4. It is obvious that k must be smaller then n. We assume 3 to 5 values for k for the experiments. Differences between i^{th} value and previous k values are computed. The maximum value of these differences is assigned to variable p. We do not consider immediate difference of light sensor data i.e. the difference between i^{th} and $(i-1)^{th}$ values as the value of light sensor may change gradually when a vehicle slowly enters the parking space. After obtaining the value of p we calculate $dr[i]$ which works as an adaptive threshold.

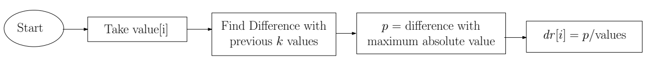


Figure 4: Flowchart for *dr* calculation.

C. Temperature Detection Algorithm

When a vehicle passes over, or park over an installed sensor node, the ambient temperature around the node increases. The heat exhausted from the vehicle may increase the temperature of the sensor. We have utilized both object temperature sensor and ambient temperature sensor to detect the temperature of the vehicle for reliable detection. For high vehicles, under which the height between the vehicle bottom and the ground is large, the object temperature measurement does not experience significant change. The reading of vehicle temperature may not be higher than the reading of sensor ambient temperature for high vehicles. To overcome this problem, we consider the average of the object temperature for the detection. As the sensor node is not moving and it is facing upward, the average of object temperature without vehicle is constant. The flowchart of the algorithm for detecting vehicle temperature is shown in Figure 5.

The algorithm for temperature sensors is similar to the algorithm for magnetic sensor. We compute the standard deviation and mean of the readings of both object and ambient temperature sensors. Unlike magnetic sensor, temperature and ambient sensors experience change only in the positive direction due to heat exhaust of the vehicle. We compute the threshold that also incorporates app-preference as explained in Section IV-A. The algorithm takes the last k readings and the average of the last k values is checked against the threshold and finally concludes with a vehicle present or absent decision.

D. Combined Detection Algorithm

The combined detection algorithm incorporates the decision of all sensors and provides the final decision on vehicle presence. The combined flowchart of the algorithm is presented in Figure 6. It is assumed that the system starts with no vehicle state. At this situation more than 100 sensor values of magnetic and temperature sensor are taken. These values are denoted as n. The thresholds are calculated and saved in the database. If any type of rebooting of the sensor node is needed, then the threshold will be supplied to the node from the database. This approach makes the maintenance easier. Variable k must be smaller than n. This system detects the vehicle after some time of vehicle arrival. The time depends on the value of k. We have taken average of k to handle spike. By using these k values magnetic sensor detection is checked. If vehicle is detected by magnetic sensor and the previous state value of the car space is present, it implies that the state is not changed. But if the previous state of the car-space value is absent, it implies a new vehicle has arrived and the degree of class is determined Table I. If vehicle is not detected by the magnetic sensor and the previous state of the car-space value is absent, it implies no vehicle has arrived. But if previous state of the car-space value is present, the decision is made based on light sensor reading. Because light sensor will determine the shadow under the car. We are not using temperature sensor after sensing shadow as when a vehicle stays on a place for a long time,

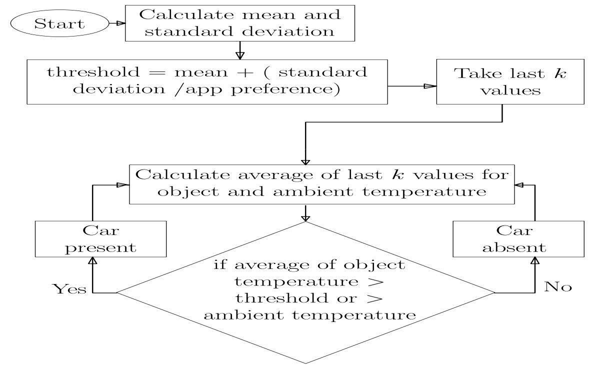


Figure 5: Flowchart for detecting vehicle temperature.

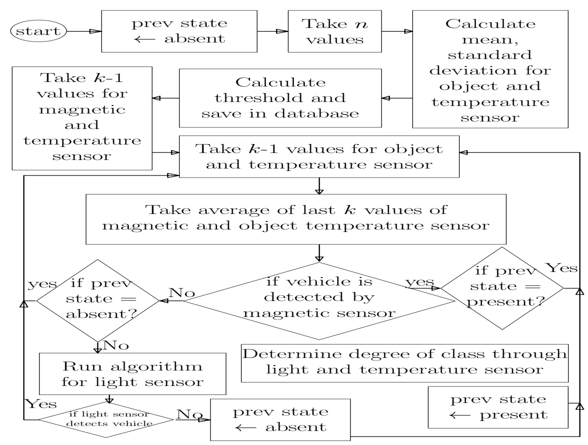


Figure 6: Flowchart for full system.

the temperature under the vehicle becomes same as natural temperature. This system will detect a vehicle and if the state changes (vehicle absent state to present or vice versa), the change will be saved in database.

V. Experiment

We have implemented the proposed system and install the system in a parking area. First we focus on the experimental setup of the system and then we present the obtained result on vehicle presence.

A. Experimental Setup

In a parking area, there are many vehicles. The data communication among the nodes may be disrupted due to the presence of many vehicles. Even the node may be disconnected. To handle this problem we use *mesh* networking. As the sensor nodes are of low power and limited memory, we have used 6lowpan [18] based operating system Contiki [17] that enables IoT and optimizes the power issues of the sensor nodes. All these nodes are connected to internet through a *border router*. The border router maintains all networking among the sensor nodes and the web server. The web server provides information of empty parking spaces to the drivers. We have used open source border routing solution 6lbr [21]. The 6lowpan is based on IPv6 but internet is based on IPv4. For converting between IPv6 and IPv4, we have used another open source software WrapSix [22].

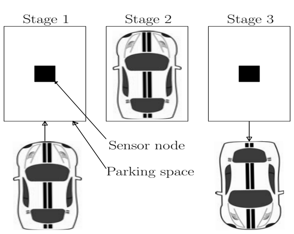


Figure 7: Three stages for each parking space: Stage 1. A car is entering the space, Stage 2. A car is over the sensor node, State 3. A car is exiting the space.

We need a sensor node that has the required four sensors: magnetic, light, object temperature, and ambient temperature sensors, and networking capability. The sensor mote should be small in size for installation flexibility. We have used TI's cc2650 [16] sensor mote that has ten sensors including the four we required. Latest version of Contiki [23] has been ported for this sensor node. We the device driver for magnetometer is not ported in Contiki. We have ported the device driver for magnetometer of InvenSense [24] in the operating system. As border router we have used BiggleBoard black [16] platform. As a MQTT client, we have used Paho [25]. As mentioned before for storing data we have used MQTT. Our sensor node is the publisher and as broker we use open source Mosquitto [15]. A laptop works as subscriber and the laptop gets the real time vehicle data and stores the data in a global database. As a MQTT client we use Paho [25].

B. Experimental Evaluation

To test the vehicle detection system proposed we placed a sensor on a parking space. The parking space can be in any of three stages as shown in Figure 7. In stage 1, a car is entering the space; in stage 2, a car is over the sensor node; and in stage 3 a car is exiting the space. The system will determine whether a vehicle is over the sensor (state 1) or not (state 0). The sensor mote was not precisely placed along the horizontal axis of the earth so that it could capture real scenario where it is not guaranteed to place the sensor perfectly. Many vehicles came and parked over the sensor. The node was connected with a boarder router wirelessly. This border router did the communication with internet. The experiment is carried out over 100 different vehicles. After detecting the vehicle the sensor node successfully stored the information in the global database.

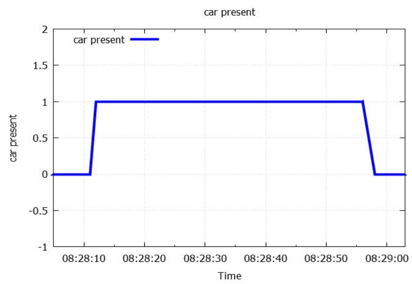
In every following plots, time is plotted along x axis and the readings of the sensors are plotted along y axis. Figure 8(a) is the ideal scenario on the state of vehicle presence. Figure 8(b), (c), (d), (e), (f) is the corresponding light, temperature (ambient and object), magnetic (x, y, z) sensor readings. The data presented in Figure 8 is for such a vehicle under which the gap between the vehicle and the sensor node is low. The light sensor reading is very small (Figure 8(b)) indicates sufficient shadow is detected. When the vehicle came the object temperature went higher than the ambient temperature (Figure 8(c)). The standard deviation of y axis of magnetometer was smallest and the z axis experienced the highest change in value. From Figure 8(d), (e), (f) we see that for vehicle arrival y axis reading does not change. But the change occurs significantly along x and z axes.

There are few cases where our system fails. For a motor bike or a bicycle, the system cannot detect properly as the amount of metal and shadow is negligible, the heat produced by this type of vehicles is not significant. The detection of bike falls in class C or D of Table I. For the vehicles made of carbon fibre, the magnetic sensor does not exhibit necessary changes and hence our system unable to detect those cars. Thus the experimental accuracy becomes 98% in our experiments.

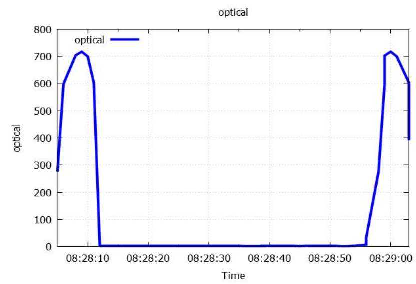
VI. Conclusion

This paper presents an end-to-end parking space management system using wireless sensor networks. The parking space is equipped with wireless sensor motes having four sensors to detect vehicle presence in a parking space. The presence and absence status of each parking space is stored in a global database. We have implemented the system using recent sensor motes and open source operating systems and protocols to support IoT architecture. We proposed algorithms do detect vehicle presence and our system is experimentally successful for 98% vehicles. It is evident that such a system using wired system alternatives would be highly expensive in compare to our system.

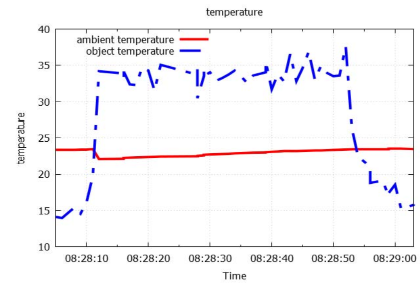
Our system fails to detect carbon-fibre cars that are a recent trend in modern vehicular revolution. We intend to solve this issue using other sensor data. In this paper we concentrate



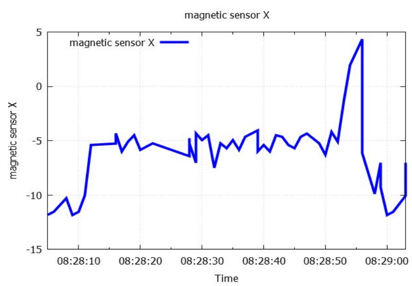
(a) Vehicle state (absent=0/present=1).



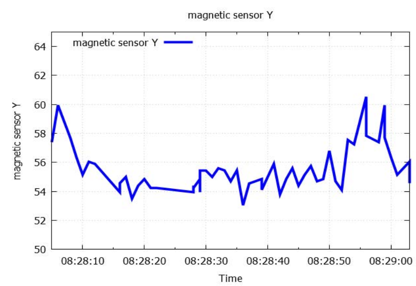
(b) Light sensor reading.



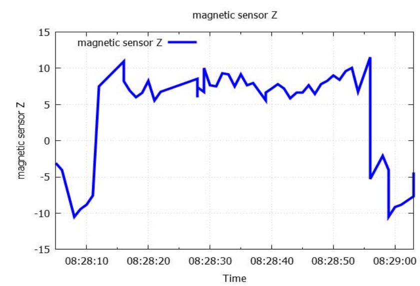
(c) Object and ambient temperature.



(d) Magnetometer reading of x axis.



(e) Magnetometer reading of y axis.



(f) Magnetometer reading of z axis.

Figure 8: Sensor readings of vehicle detection.

on the accuracy of the system. This paper does not consider power efficiency issue and security issue of wireless sensor network. All these issues together would be an extension of this paper.

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