Available online at www.sciencedirect.com
ScienceDirect
Procedia Computer Science 83 (2016) 385 – 392
Procedia Computer Science

The 7th International Conference on Ambient Systems, Networks and Technologies (ANT 2016)

# Performance Analysis of Proximity and Light Sensors for Smart Parking

Mamta Bachani[a], Umair Mujtaba Qureshi[a,b,*], Faisal Karim Shaikh[a]

[a] *Dept. of Telecommunication Engg., Mehran University of Engineering and Technology, Jamshoro, Pakistan*
[b] *Dept. of Computer Science, City University of Hong Kong, Kowloon Tong, Hong Kong*

**Abstract**

The rapid increase in vehicle population in recent years have given rise to a number of global problems such as air pollution, blockage of roads, waste of fuel and time. These issues exist due to the congestion caused by vehicles while finding the parking slot especially in metropolitan cities. Even today, many of the existing parking systems provide a passive information to the drivers regarding the availability of parking slots. Currently, the sensors deployed for detecting the vehicle presence in parking facilities are not reliable and are expensive. This paper presents a comprehensive analysis on crucial aspects for designing a smart parking system such as sensor selection and optimal position for sensor deployment for accurate detection. Initially, two most common sensor, Light Dependable Resistor (LDR) sensor that works on shadow detection principal and Infra-Red (IR) sensor which works on object detection mechanism are used. The performance analysis of the accuracy for detection of vacant parking slots and vehicle detection under different conditions is presented. It is concluded that IR sensor outperforms LDR sensor in terms of it's accuracy in detecting the vacant parking slots and vehicle detection in different environmental factors.


Peer-review under responsibility of the Conference Program Chairs
*Keywords:* Smart Parking System; Wireless Sensor Network; IR Sensor; Light Sensor

## 1. Introduction

Vehicles are considered as one of the fundamental facility for humans today. With increasing human population, the vehicle population has also increased, crossing 1 billion in 2013 throughout world[1]. This rapid increase in vehicle population has lead to some very challenging global problems such as air pollution, blockage of roads, wastage of fuel, time and disturbance to the people on daily basis. One of the primary reason have been long vehicle congestions on main roads and especially while finding the vacant places or slots for parking in many major cities. Even today, in many major cities, the existing parking systems are very traditional and provides a passive information regarding the parking slot availability to the drivers. Thus, this problem calls for serious considerations for making in existing parking systems, smart. Existing parking systems include manual systems of parking in which a parking officer

* Corresponding author. Tel.: +852 5122 0433
*E-mail address:* umqureshi2-c@my.cityu.edu.hk


Peer-review under responsibility of the Conference Program Chairs
doi:10.1016/j.procs.2016.04.200

assists the driver to find a vacant place for the vehicle[2]. Hence, it becomes even more difficult for the parking officer to manage if the parking area and spaces increases. Moreover, the problems of when and where is the current vacant of parking slot, navigation of the vehicle towards the correct parking slot and charging tickets manually just add even more difficulties to the existing problems in traditional parking systems. Therefore, these problems can be addressed by designing an intelligent, smart parking system. By smart parking system it is meant that with the help of sensor technology, the system should be intelligent enough to manage the entire parking system autonomously.

Wireless Sensor Networks (WSN) is an enabling technology, which is based on autonomous sensors, deployed in an area to sense different physical parameters, such as parking slot vacancy, vehicle detection and etc [3]. These sensors communicate wireless amongst themselves and with central base station, where entire information fromt he sensors is collected and post processed [4]. Thus, with the help of wireless operating autonomous sensors, a WSN based smart parking system can be developed.

Though, there has been tremendous amount of research in recent years in making the existing parking system intelligent through different technologies such as Global Positioning System (GPS)[5] based system, Global System for Mobile Communication (GSM)[6] based systems, Radio Frequency Tag/IDs (RFIDs) based systems[1], and likewise many others. Even then, while designing a reliable sensor based parking system, there has always been a confusion on two post important factors that is 1) Best sensor and 2) Best location for the sensor deployment for accurate and reliable parking slot detection and vehicle detection.

This paper would like to address these questions once and for all by presenting detailed discussion on sensor selection and sensor optimal deployment. The most widely used sensors are Light Dependable Resistor (LDR) sensor, Infra-Red (IR) sensor and Magnetic sensor. Initially, LDR sensor and IR sensor and Magnetic sensor are used to detect the vehicles. These sensor can be categorized as proximity sensors. Reason of using these sensors is the cost, as they are cheap and use less memory in comparison to camera if used as a sensor. And also, these sensors are more reliable compared to weight or pressure sensors. Therefore, these sensors can be critical in formulating WSN based smart parking system, a cost effective system. However, their accuracy and reliability in detecting vehicles is yet to be addressed.

Thus, this paper presents the performance analysis of proximity sensors (LDR and IR sensor). As a case study, a test bed is designed where the sensors are deployed in an open parking facility to detect vacant parking slots, vehicles and types of vehicle detection and accuracy of detection in varying environmental conditions.

The rest of paper is organized as follows. Section 2 presents the related work. Section 3 introduces a WSN based Smart Parking System, discusses the theory of operation of the LDR and IR sensors. Section 4 provides detail discussion on experimental scenarios and presents the performance analysis of proximity sensor for smart parking systems. Finally, Section 5 concludes the paper.

## 2. Related Work

To design a smart parking system, the most important phase is the detection of vehicle accurately. Also, the information has to be disseminated reliably to central base station. There are various sensors and different approaches which are used to detect the vehicles[7,8,9,10,11].

Yamada et al.[12] and Banerjee et al.[13] have used surveillance cameras and image processing techniques to check the availability of vehicle in a parking. This is one of the most common techniques utilized in current parking systems but this method lacks in accuracy due to a number of reasons such as indoor and outdoor environments, shadow effects and distortion effects. Amin Kianpisheh et al.[14] have used Ultra Sonic sensor to detect the vehicle. Ultrasonic sensor is one of the possibility of detecting vehicle accurately to a certain extent. However it has some disadvantages, particularly sensitivity to temperature changes and extreme air turbulence which makes ultrasonic sensor not suitable for smart parking system. Where as in[15], the authors have proposed acoustic sensor for detection an empty parking slot however its reliability in a congested and noisy environment restrain it to be suitable for vehicle detection and parking system. V.Venkateswaran et al.[16] have used Infra Red (IR) sensor to detect the vehicle. Detection of vehicle through IR sensor is one of the most sensible approach but the approach is complicated as the authors are using separate IR transmitter and a separate IR receiver. Moreover, the authors have simply proposed of using IR sensors while its accuracy and reliability still remains a question to be addressed. Pala et al.[17] have proposed vehicle detection through RFID/Tag technology. Vehicle detection is one of the most accurate ways by tagging vehicles. However, on a large scale RFID/Tag based vehicle detection for parking is still not adopted due to two reasons. First the location of tag to be placed and second the over all cost of the system, which makes commercial adoption pace slow. Wei et al.[18], the authors have proposed Vehicular Ad-hoc Networks (VANETS) for smart parking system. VANETs are specifically designed for vehicle related applications. However, the implementation of VANETs through the world is a slow process. Moreover, VANET architecture is costly and also deploying a whole VANET only for parking system is not suitable. The authors of[19], have also proposed VANETs for detecting vehicle while information dissemination is carried through short message service (SMS). Hongwei Wang et al.[20] have proposed reservation based smart parking system. The proposed system uses light and vibration sensors to detect the vehicles. The authors have mainly focus on detecting the traffic congestion in scenario where a vehicle has to search for an empty parking slot. The authors have alleviated the traffic congestion by their proposed system. However the authors have neither considered environmental impairments which can cause false detection through vibrations nor have they considered different environmental conditions and factors which can mislead the detection of vehicles through light sensors. Srikanth et al.[7] have designed and Implemented a Prototype Smart PARKing (SPARK) System using WSN, but the prototype is impractical as the sensor selected for the prototype are vulnerable to environmental conditions and different non-target objects. Quinones et al.[21] have proposed an architecture to design a smart parking system using wireless sensor network. There work mostly concentrated on reliable information dissemination or connection based on the topological network design using zigbee 900 and Digimesh 2.4 GHz. Gupta et al.[22] have proposed intelligent context-aware parking-space location mechanism through integrating Integrating pervasive computing, infostations and swarm intelligence. The research concentrates on detection of vacant parking slots and sorting a shortest reliable path towards the based stations, using any sensor. Similarly, Asaduzzaman et al.[23] presents a comparative analysis of wireless technologies such as Wifi, Bluetooth and Zigbee and proposed Zigbee as a time and energy efficient parking system and does not states any description of sensor and its precision. Junzhao et al.[24] proposed a multi-classifier image based vacant parking detection system using camera sensor for detection. A camera can be used as sensor detect the vacant parking slots or vehicles, however it is vulnerable darkness (low intensity), which require complex algorithms. Thus, such systems are costly and highly complex. Rest of the researches[25],[26],[27] proposed different architecture for developing WSN based smart parking systems.

The literature presented above propose different WSN based parking systems that can be used for detecting vehicles however, there are many factors and aspects that needs to be considered. Factors such as, precision in vacant parking detection and vehicle detection under different non-target elements such as living things (humans or animals) or other than vehicle objects. Also location of the parking system such as, indoor or outdoor, as the visibility plays an important role for some sensors. Similarly, the environmental conditions like weather (cloudy or dusty) can also impair the performance of the sensors and lead to false detection. Therefore, keep such factors and aspects in consideration, the existing literature lacks in such considerations which makes the precision of different sensors ambiguous and can lead to false detection. This research paper presents performance of LDR sensor with IR sensor and gives the comparative analysis in terms of their accuracy and reliability under different environmental conditions.

## 3. Comparison Framework

In this Section, a WSN based smart parking system is presented. The prototype consists of a network of wireless sensors are deployed in parking area which detects the availability of a parking slot for the vehicles, disseminates the information to the drivers. In order to ease the drivers, an android application is designed that facilitates the drivers regarding the vacant parking slot and helps in navigation through maps.

To design a reliable and efficient WSN based parking system, the first phase is the deployment of the sensors. Initially a single parking slot is considered, where sensors can be deployed. There are two important considerations, 1) The type of sensor to be used, 2) The location of the sensor to sense the vehicle. There are different sensors that can be used and deployed to sense the vehicle presence or absence. Initially, LDR Sensor and IR sensor are used for performance evaluation. For using any kind of sensor, the most important and crucial consideration is the location of the sensor deployment. The deployment of the sensor depends on the environment (Indoor/Outdoor) of the network. In an indoor environment, the sensor can be deployed beneath the roof or on the walls or on the floor or even all around a single slot. While in an outdoor environment, the sensor is planted in the floor of the parking slot. Planting sensor in the floor is the most common method used as it is considered as an environment independent location. Therefore, with a proper sensor selection and deployment, the presence and absence of the vehicle at a single parking slot is monitored. Once a single parking slot is monitored, it can than be generalized for other parking slots. Therefore, a mesh network is laid where, each sensor is connected to every other sensor. The information is transmitted to the base station using Collection Tree Protocol (CTP) [28]. For analysis, the information is uploaded on server via File Transfer Protocol (FTP) once the data is collected at base station. The same information is transferred to the FTP Server and is periodically updated at the server at every 5 seconds. A smart mobile android application is designed that can fetch the information from the FTP server and indicate the available parking slot to its users at anywhere at any time.

The prototype system is generalized in a sense that it can be deployed anywhere (indoor or outdoor) and the system should sustain in every environmental/weather conditions. In order to design a reliable and robust sensor network, the first and foremost step is the selection of sensor to detect the availability and unavailability of the parking slot through the presence and absence of vehicle. Since LDR and IR sensor are used, it is important to understand their theory of operation for each sensor/ The working principle of both sensors is discussed below:

### *3.1. Light Dependent Resistor (LDR) Sensor*

The first sensor used is Light Dependent Resistor (LDR) Sensor. LDR sensor is integrated with crossbow's MDA100CA sensor board[28]. The LDR sensor works on shadow detection method. In shadow detection method, whenever there is presence of light or luminous source such as Sun, it calculates the luminous intensity.[29]. The absence of luminous intensity creates a shadow. If an LDR sensor is deployed beneath a vehicle, the presence of a vehicle creates a shadow over the LDR sensor. Indicating unavailability of a parking slot. Similarly, the absence of vehicle will not create any shadow. Indicating availability of a parking slot. In this way, LDR sensor is used to detect the vehicle in smart parking system.

### *3.2. Infrared (IR) Sensor*

The second sensor used to design smart parking system is Sharp Technologys IR Sensor. IR sensor works on object detection method. In object detection method, whenever there is presence of any object within the Line of Sight (LOS) of IR sensor, a part of the signal is will reflect back in the direction of IR sensor[30]. This reflected signal is called an echo signal. If an IR sensor is deployed in a parking slot, the presence vehicle will obstruct the LOS of IR signal, resulting in an echo signal, indicating the presence of a vehicle in the parking slot. Similarly, the absence of vehicle will not result in any echo signal. Indicating the availability of the free parking slot for vehicles to be parked. In this way, IR sensor is used to detect the vehicle in smart parking system.

May it be Crossbows LDR Sensor or Sharp technologys IR sensor, it is necessary to conduct a detail performance analysis and test these sensors in light of accuracy of vehicle detection, reliable information dissemination and their working vulnerability in different environmental factors and aspects.

## 4. Results

In this Section, the above two proposed sensors (LDR Sensor and IR Sensor) are considered, deployed and tested in different self-made scenarios under real time conditions to check the sensor precision in terms of its reliability. The experimentations are initially conducted at a single parking slot. The results of the two sensors are observed under same physical parameters and conditions using different types of vehicles. The scenarios are detailed below:

### *4.1. Scenario 1: Vehicle Detection using Light Sensor:*

LDR Sensor works on Shadow Detection Method. The detection of vehicle using LDR sensor results from the change in the value of luminous intensity. There are different sources of luminous intensity. In our case, Sun is considered as the primary source of the luminous intensity. The experiments are conducted by deploying Crossbows IRIS motes[28]. Crossbows MDA100CA sensor unit has an embedded LDR sensor. The IRIS mote is implanted in the surface in a single parking slot to detect the vehicle. The sensor is deployed at the center of the ground of parking slot in a manner that the sensors aperture is fully exposed with 90 degree upwards from its surface as shown in the Fig. 1.

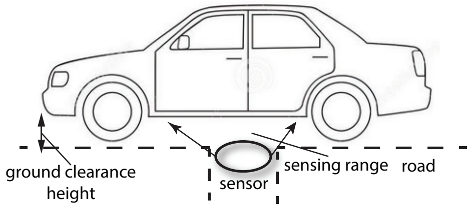
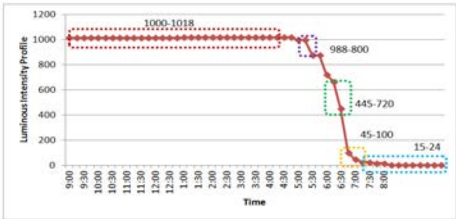
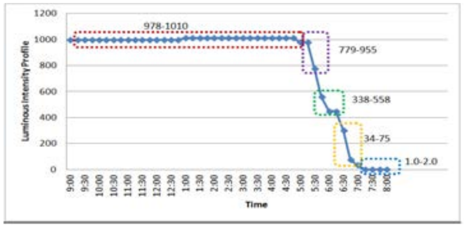



Fig. 1: Sensor deployed at the center of the ground in a Parking Slot




(a) Profile without Vehicle Parked




(b) Profile With Vehicle Parked

Fig. 2: Luminous Intensity Profiles

In order to detect the parked vehicle, it is important to calculate an overall luminous intensity profile (from morning to late evening) of the sun at an vacant parking slot. The profile indicates and helps to set a threshold. When any vehicle arrives at the parking slot, it will be parked over the LDR Sensor, which will intersect the contact of the sun light with sensors surface aperture, creating a shadowing effect. Thus, resulting in a significant decrease in luminous intensity. The value of the luminous intensity at which the shadow will be created over the sensor, is the threshold value. Which is used as a reference, for vehicle detection in future. Therefore, initially the sensor is deployed at the center base of the parking slot to monitor the luminous intensity profile of the sun from 9:00 AM in morning till 7:00 PM in an empty parking slot as shown Fig. 2(a)

The Fig. 2(a) represents the range of luminous intensity values at different time intervals. The graphs indicates the values of luminous intensity from 9:00 AM, when the Sun is approximately 25 degree angle with respect to the sensor. As the day progresses, it is evident from the Fig. 2(a) there is significant increase in luminous intensity level from 12:30 PM to 3:30 PM. Because, Sun is at its peak, crossing at around 90 degree angle over the sensors aperture that enables the maximum direct fall of the light over the LDR sensor. Interestingly, Fig. 2(a) shows a smooth graph of the luminous intensity from 9:00 AM to 5:30 PM. However from 5:30 PM onwards, there is a drastic decrease in the luminous intensity profile. This is because as the Sun sets off in evening, the luminous intensity decreases. Therefore, from 7:00 PM onwards the luminous intensity is lowest due to the absence of the Sun. During the absence of the Sun, the light of the moon and other surrounding Lights (Such corridor bulbs, street lights and etc.) becomes the source of the luminous intensity.

When the vehicle is parked in the parking slot, a shadow is created and the luminous intensity is decreased as shown in Fig. 2(b). The graph in Fig. 2(b) notifies a significant decrease in luminous intensity due to the shadow effect of the vehicle at the parking slot. Luminous intensity is almost linear in the day time hours. However, as the day proceeds and Sun starts to set off in the evening, there is gradual decrease in the luminous intensity profile specifically from 5:30 PM to 7:00 PM which is evident in Fig. 2(b).

In this entire luminous intensity profile, the objective is to decide the threshold which can be range of values that can act as referencing values on the basis of which a vehicle can be detected. These values are depicted in the Table 1 shown below:

The Table 1 depicts a comprehensive detail of the entire reference values that can be used for detection of vehicle using LDR sensor with threshold reference values at different time intervals. It can be noticed that, there are different threshold values for different time intervals. In order to the detect vehicle in the parking slot from 8:00 AM to 5:00

Table 1: Luminous Intensities (LI) in Different Conditions

| Time | LI without Vehicle | LI with Vehicle | Threshold Range of LI with Vehicle |
|---|---|---|---|
| 8:00 AM 11:00 AM | 1014 | 998 | 978-1010 |
| 11:00 AM 1:00 PM | 1014 | 998 | 978-1010 |
| 1:00 PM 3:00 PM | 1018 | 1000 | 9k78-1010 |
| 3:00 PM 5:00 PM | 1018 | 1000 | 978-1010 |
| 5:00 PM 5:30 PM | 1000 | 950 | 779-995 |
| 5:30 PM 5:45 PM | 998 | 786 | 779-995 |
| 5:45 PM 6:00 PM | 720 | 554 | 338-558 |
| 6:00 PM 6:15 PM | 665 | 448 | 338-558 |
| 6:15 PM 6:30 PM | 445 | 68 | 34-75 |
| 6:30 PM 6:45 PM | 100 | 22 | 34-75 |
| 6:45 PM 7:00 PM | 45 | 2 | 1.0-2.0 |
| 7:00 PM 7:30 PM | 24 | 1 | 1.0-2.0 |
| 7:30 PM 8:00 PM | 15 | 1 | 1.0-2.0 |

PM, there is single threshold range. However the from 5:00 PM to 7:30 PM, there are 4 different threshold ranges. Therefore, for each time interval there will be different threshold range value for proper detection of the vehicle.

#### *4.1.1. Analysis*

The premier advantage of LDR sensor is that it is simple to use and integrate. However, working vulnerability in detecting vehicle accurately is highly disturbed due to number of factors which are it's disadvantages. The values of luminous intensity varies with different environmental parameters for the detection of vehicle such as, whether the parking is under shelter or without shelter, height of vehicle from the base of parking slot, location of the parking slot with respect to the angle of arrival of the Sun light (i.e. east, west, north and south), environmental effects (such cloudy, bad weather), time interval because luminous intensity of the Sun decrease as the day progresses within 24 hours time which creates more than one threshold values, thus increasing the algorithm code complexity and also duration of a day differs 365 days a year. These all factors have severe impact over the accuracy of LDR sensor to detect the vehicle efficiently.

### *4.2. Scenario 2: Vehicle Detection using Infrared (IR) Sensor:*

Infrared (IR) sensor works on Object Detection Method. Object Detection Method is based on detection of any object of interest with in its range[31]. Any object that comes within the LOS of an IR sensor, an echo signal is generated. The reception of any echo signal indicates the presence of the object whereas the strength of the echo estimates, how the far is the object. The experiment is conducted using Crossbows IRIS motes. To have compatibility of Infrared (IR) sensor with IRIS mote the Crossbows sensor MDA300 is integrated with the Infrared (IR) sensor along with external battery supply of 4.4-5.0 volts. The IRIS sensor integrated with IR sensor, is deployed at the center of the base of parking slot, with its area of aperture totally exposed upwards as shown in Figure2. Initially, when the parking slot is vacant, there will be no echo signal because there is no any vehicle (object of interest) within the LOS range. Since, IR LOS is not intersected, it produces 0 volts. The entire signal will spread and loss. Whenever any vehicle arrives over the sensors aperture, the IR signal will be intercepted, resulting in echo signal. Upon reception of an echo signal, there will be a significant amount of voltage generated by the echo signal indicating the presence of the vehicle. Detection of vehicle using Infrared (IR) sensor is the change in the value of voltage level. This change in voltage level is directly proportional to the distance. In this scenario, it is the height of the vehicles base from the sensors aperture. As signal tends to spread with distance, greater the height of the base of the vehicle, greater the signal will spread and the echo signal will be weak. Similarly, the more closer be the base of the vehicle with respect to sensors aperture, signal will spread less and echo signal will be stronger.

In order to have comparative analysis in the light of detecting the vehicle accurately, the parameters considered for scenario 1 for the LDR Sensor are kept same. IRIS integrated with IR sensor is deployed at the base of parking slot from morning 9:00 AM to 8:00 PM. The parking slot is empty, therefore there will be no interception in the IR signal, and no echo signal will be generated. The voltage level will be 0 volts. This is the reference voltage level. When vehicle arrives over the deployed sensor in the parking slot, IRs LOS will be intercepted, generating an echo signal. The voltage level will change from 0.0 volts which is considered as reference voltage up to a level which depends on the height of vehicle's base and resulting an echo. Fig. 3 shows that voltage level remains 0 volts in the absence of the vehicle. Whenever any vehicle arrives at the parking slot, a certain voltage level is observed, resulting in detection of

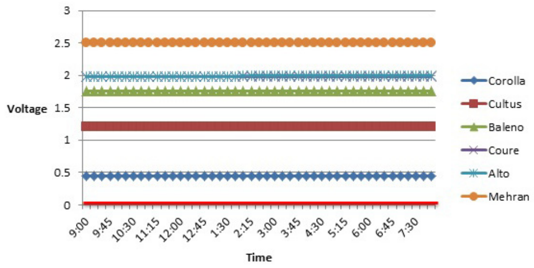



Fig. 3: Vehicle Detection using IR Sensor

the vehicle. The voltage level after detection of a particular vehicle remains same for the entire time interval i.e. 9:00 AM to 8:00 PM as highlighted in Fig. 3. Thus Infrared (IR) sensor can be considered as accurate for the detection of vehicle.

#### *4.2.1. Analysis*

The premier advantage of IR sensor is the accuracy of the detecting vehicles. Unlike LDR sensor, IR sensor is less vulnerable to the environmental conditions. Factors such as whether the parking slot is under shelter or without shelter, location of the parking slot with respect to the angle of arrival of the Sun light (i.e. east, west, north and south), environmental effects (such cloudy, bad weather), different time intervals, change in luminous intensity of the Sun in 24 hours time and also duration of a day difference in 365 days of a year, has no any impact over the performance of the IR sensor in comparison to LDR Sensor. These factors greatly influence the performance of LDR sensor. The sole disadvantage is the IR sensors, is they are not cost effective.

Interestingly, the only change and variation which can be observed in the results is with respect to the height of the base of vehicle from sensors aperture. This is indeed a variation however with this variation the detection of different types can be made as shown in Table 2. Here, the reference voltage is set to 0.

Table 2: Results of Infrared Sensor

| Type of Vehicle | Voltage with Vehicle Parked | Threshold Range |
|---|---|---|
| Toyota Corolla | 0.45 | |
| Suzuki Cultus | 1.21 | |
| Suzuki Baleno | 1.75 | 0.45 2.5 |
| Dak2itso Coure | 1.98 | |
| Suzuki Alto | 2 | |
| Suzuki Mehran | 2.5 | |

The Table 2 shows the voltage values that were observed during the experiment for each type of vehicle. Accordingly, the threshold range from 0.45-2.5 can be used for the detection of different types of vehicles.

## 5. Conclusion

To detect the vehicle and vacant parking slot, the performance of two different sensors, the LDR and IR sensor are analyzed. A comparative analysis is made in terms of their accuracy of detecting (different types) vehicles and their working vulnerability in different timings of the day under different environmental conditions. The accuracy of LDR sensor is highly affected by the change of the luminous intensity throughout the day. Therefore, different threshold values have been derived on the basis of the change in luminous intensity. This increases the code complexity and makes the vehicle detection ambiguous in specially in rainy or cloudy weather conditions. Shadow of non-object of the interest further increases the false detection in LDR sensor and hence severely impacts the accuracy its accuracy. In comparison to LDR sensor, IR sensor proves to be better sensor for vehicle detection as the performance of the IR sensor is not effected by any environmental conditions like LDR sensor. IR sensor has capability of identifying different types of vehicles unlike LDR sensor. The sole disadvantage of IR sensor is that it consumes more energy that makes it less cost effective in comparison to LDR sensor.

## References


1. L. Stenneth, O. Wolfson, Bo Xu, and P.S. Yu. Phonepark: Street parking using mobile phones. In *Mobile Data Management (MDM), 2012 IEEE 13th International Conference on*, pages 278–279, July 2012.
2. J. Rico, J. Sancho, B. Cendon, and M. Camus. Parking easier by using context information of a smart city: Enabling fast search and management of parking resources. In *Advanced Information Networking and Applications Workshops (WAINA), 2013 27th International Conference on*, pages 1380–1385, March 2013.
3. J. Yick, B. Mukherjee, and D. Ghosal. Wireless sensor network survey. *Computer Networks*, 52(12):2292 – 2330, 2008.
4. P. Rawat, K. Singh, H. Chaouchi, and J. Bonnin. Wireless sensor networks: a survey on recent developments and potential synergies. *The Journal of Supercomputing*, 68(1):1–48, 2014.
5. Y. Rahayu and F.N. Mustapa. A secure parking reservation system using gsm technology. *International Journal of Computer and Communication Engineering*, 2:518–520, 2013.
6. M. Jian, K.S. Yang, and C. Lee. Modular rfid parking management system based on existed gate system integration. *WTOS*, 7(6):706–716, June 2008.
7. S.V. Srikanth, P.J. Pramod, K.P. Dileep, S. Tapas, M.U. Patil, and C.B.N. Sarat. Design and implementation of a prototype smart parking (spark) system using wireless sensor networks. In *Advanced Information Networking and Applications Workshops, 2009. WAINA '09. International Conference on*, pages 401–406, May 2009.
8. S.C. Khang, T.J. Hong, T.S. Chin, and S. Wang. Wireless mobile-based shopping mall car parking system (wmcps). In *Services Computing Conference (APSCC), 2010 IEEE Asia-Pacific*, pages 573–577, Dec 2010.
9. J.P. Benson, T. O'Donovan, P. O'Sullivan, U. Roedig, C. Sreenan, J. Barton, A. Murphy, and B. O'Flynn. Car-park management using wireless sensor networks. In *Local Computer Networks, Proceedings 2006 31st IEEE Conference on*, pages 588–595, Nov 2006.
10. R. Souissi, O. Cheikhrouhou, I. Kammoun, and M. Abid. A parking management system using wireless sensor networks. In *Microelectronics (ICM), 2011 International Conference on*, pages 1–7, Dec 2011.
11. J. Jeffrey, R.G. Patil, S.K.K. Narahari, Y. Didagi, J. Bapat, and D. Das. Smart parking system using wireless sensor networks. In *The Sixth International Conference on Sensor Technologies and Applications*, pages 306–311, Aug 2012.
12. K. Yamada and M. Mizuno. A vehicle parking detection method using image segmentation. *Electronics and Communications in Japan (Part III: Fundamental Electronic Science)*, 84(10):25–34, 2001.
13. S. Banerjee, P. Choudekar, and M.K. Muju. Real time car parking system using image processing. In *Electronics Computer Technology (ICECT), 2011 3rd International Conference on*, volume 2, pages 99–103, April 2011.
14. A. Kianpisheh, N. Mustaffa, P. Limtrairut, and P. Keikhosrokiani. Smart parking system (sps) architecture using ultrasonic detector. *International Journal of Software Engineering and Its Applications*, 6(3):55–58, 2012.
15. K. Na, Y. Kim, and H. Cha. Acoustic sensor network-based parking lot surveillance system. In *Proceedings of the 6th European Conference on Wireless Sensor Networks*, EWSN '09, pages 247–262, Berlin, Heidelberg, 2009. Springer-Verlag.
16. V Venkateswaran and N Prakash. Intelligent approach for smart car parking reservation and security maintenance system. *IJRET: International Journal of Research in Engineering and Technology*, 3(02), 2014.
17. Z. Pala and N. Inanc. Smart parking applications using rfid technology. In *RFID Eurasia, 2007 1st Annual*, pages 1–3, Sept 2007.
18. L. Wei, Q Wu, M. Yang, W. Ding, B. Li, and R. Gao. Design and implementation of smart parking management system based on rfid and internet. In *Control Engineering and Communication Technology (ICCECT), 2012 International Conference on*, pages 17–20, Dec 2012.
19. N.H.H.M. Hanif, M.H. Badiozaman, and H. Daud. Smart parking reservation system using short message services (sms). In *Intelligent and Advanced Systems (ICIAS), 2010 International Conference on*, pages 1–5, June 2010.
20. H. Wang and W. He. A reservation-based smart parking system. In *Computer Communications Workshops (INFOCOM WKSHPS), 2011 IEEE Conference on*, pages 690–695, April 2011.
21. M. Quinones, V. Gonazalez, L. Quinones, C. Valdivieso, and W. Yaguana. Design of a smart parking system using wireless sensor network. In *Information Systems and Technologies (CISTI), 2015 10th Iberian Conference on*, pages 1–6, June 2015.
22. A. Gupta, V. Sharma, N.K. Ruparam, S. Jain, A. Alhammad, and M.A.K. Ripon. Integrating pervasive computing, infostations and swarm intelligence to design intelligent context-aware parking-space location mechanism. In *Advances in Computing, Communications and Informatics (ICACCI, 2014 International Conference on*, pages 1381–1387, Sept 2014.
23. A. Asaduzzaman, K.K. Chidella, and M.F. Mridha. A time and energy efficient parking system using zigbee communication protocol. In *SoutheastCon 2015*, pages 1–5, April 2015.
24. Junzhao Liu, M. Mohandes, and M. Deriche. A multi-classifier image based vacant parking detection system. In *Electronics, Circuits, and Systems (ICECS), 2013 IEEE 20th International Conference on*, pages 933–936, Dec 2013.
25. R.E. Barone, T. Giuffre, S.M. Siniscalchi, M.A. Morgano, and G. Tesoriere. Architecture for parking management in smart cities. *Intelligent Transport Systems, IET*, 8(5):445–452, August 2014.
26. F. Ahmad, A. Basit, H. Ahmad, S.A. Mahmud, G.M. Khan, and F.Z. Yousaf. Feasibility of deploying wireless sensor based road side solutions for intelligent transportation systems. In *International Conference on Connected Vehicles and Expo*, pages 320–326, 2013.
27. Jihoon Yang, J. Portilla, and T. Riesgo. Smart parking service based on wireless sensor networks. In *IECON 2012 - 38th Annual Conference on IEEE Industrial Electronics Society*, pages 6029–6034, Oct 2012.
28. S.R.N. Reddy V. Madan. Review of wireless sensor mote platfoms. *VSRD-IJEECE*, 2(2):50–55, 2012.
29. EFY Enterprises. *Electronics Projects Vol 22:*. EFY Enterprises Pvt. Ltd., 2014.
30. Helmut Budzier and Gerald Gerlach. *Thermal infrared sensors: theory, optimisation and practice*. John Wiley & Sons, 2011.
31. D. P. Meyer and H. A. Mayer. Chapter 2 - statistical signal detection. In D. Mayer and P. Meyerherbert, editors, *Radar Target Detection*, pages 19 – 35. Academic Press, 1973.