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Smart Parking Information System Exploiting Visible Light Communication

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Abstract

In this paper, we propose a smart parking information system exploiting visible light communication (VLC) technology to help drivers getting the real-time parking information as well as direction guide. By providing accurate information on available parking spaces, drivers save time and fuel and increase efficiency of the parking process. Therefore, the proposed system not only gives the illumination function of LED but also the function of communicating in the manner of application based on the VLC. The effectiveness of the proposed scheme is validated through experiments in an indoor environment.

Keywords: *Smart parking lot, Visible light communication, LED, Manchester code*

1. Introduction

In modern life, the shopping complexes always attract people for its good products and service. What's more, shopping complexes have begun providing services much more diverse than just pure selling and buying. Customers can use banking services, post offices, food courts, cinemas, children's play areas. Hence, more shop manager prefers to invest much money and time in designing the interior, store location, parking lots and so on to target more customers and increase revenue.

Providing sufficient parking spaces for visitors is one of the most important issues in developing shopping complexes. Offering safe and conventional parking lots with a sufficient number of spaces is a few of the factors which can increase customer loyalty and attract customers to visit a shopping mall more frequently. However, until now, various parking information systems in our life are based on conventional radio communication system, which need specific industry standard [1-3].

In addition to this, light-emitting diode (LED) offers advantageous properties such as high brightness, reliability, lower power consumption and long lifetime and smaller size. Due to this advantage of LED, more and more researcher put their attention on the optical communication system that employs LEDs for wireless networks. Visible-light communication (VLC) is a kind of optical wireless communication that uses the "visible" ray as the medium. The function is based on the fast switching of LEDs and the modulation of the visible-light waves for free-space communications. The LEDs are expected not only to serve in the next generation of lamps but also in an indoor wireless system [4-7].

Most of those current researches are focused on the VLC theory with LED [8-10]. However, the practical application emerged from VLC technique in real life is still uncultivated although it can provide plentiful economic benefits.

In this paper, for this reason, the concept of VLC scheme with LEDs is discussed and its application for smart parking information system is briefly evaluated. A novel smart parking information system exploiting VLC technology is proposed to help people

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getting the real-time parking information as well as the direction guide. By providing accurate information on available parking spaces, drivers save time and fuel and increase efficiency of the parking process. Therefore, the proposed system not only gives the illumination function of LED but also the function of communicating in the manner of application based on the VLC simultaneously. The effectiveness of the proposed scheme is validated through experiments in an indoor environment.

This paper is organized as follows. The system description details the structure of the smart parking information system in Chapter 2. Chapter 3 analysis the performances of various LEDs via experiment in an indoor environment. Finally, the last section offers discussion and future researches.

2. System Description

In this section, the detail of the novel smart parking information system using VLC technology is descripted. Figure 1 describes briefly the structure of smart parking lot system. The system can be divided into three major parts of entrance of parking lot, process of finding a parking space and proceeding of parking areas.

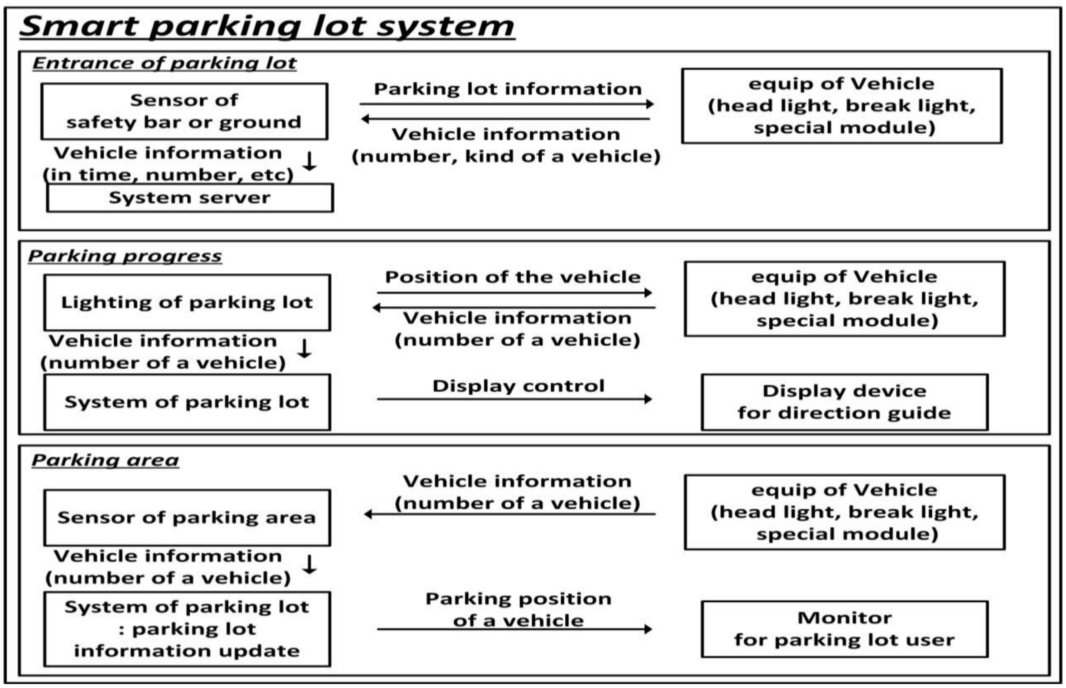

Figure 1. System Description of Smart Parking Lot using VLC

2.1. Parking Entrance

In the parking entrance, VLC module of safety bar, ground or ceiling and head light or installed VLC module in car are communicating. In this process, parking lot system send data about empty parking space, map of parking lot, and vehicles also send data about number, kind, *etc.*, Smart parking lot system can guide vehicles for parking, and all information is stored in a system server. This information can be used for fee payment, parking management, *etc*. Figure 2 shows structure of parking lot entrance. The VLC module of safety bar or ground receives the information of vehicles coming from the head light. The VLC module of celling can receive the information from the installed module in the car.

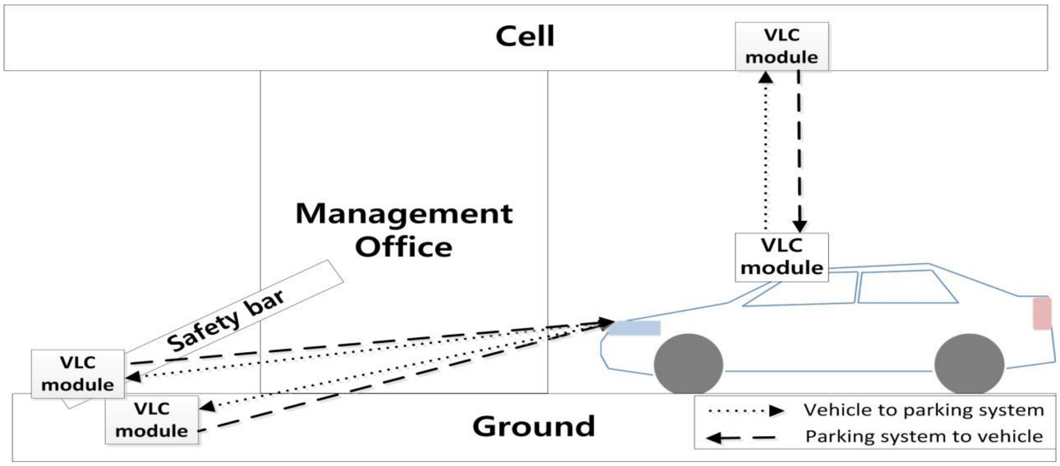

Figure 2. Structure of Parking Lot Entrance

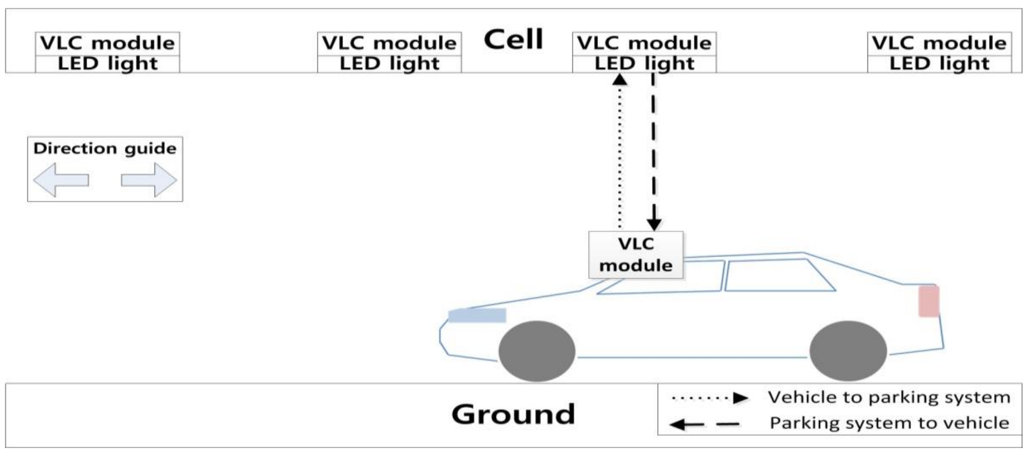

Figure 3.Structure of Process for Finding Parking Space

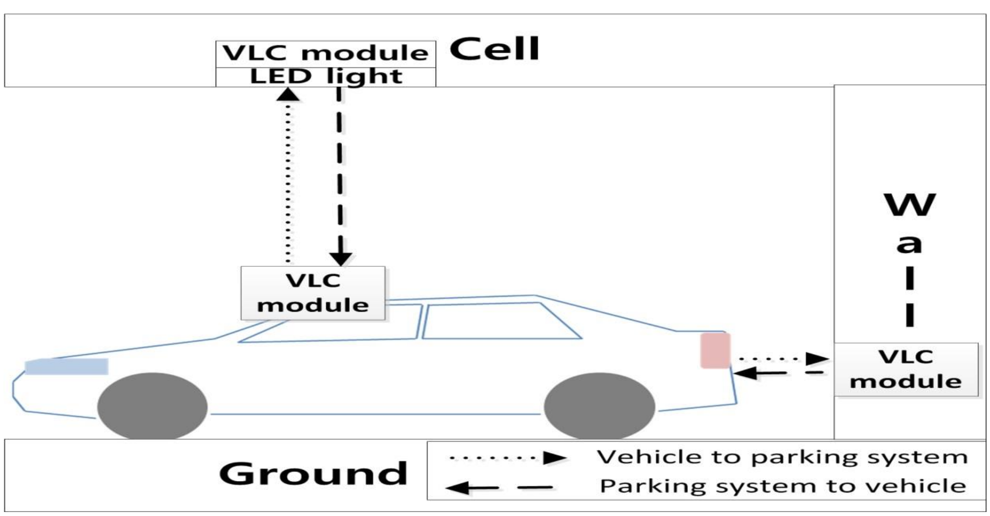

Figure 4. Structure of Parking Area

2.2. Process of Finding a Parking Space

This process consists of VLC possible lights in the parking lot, installed VLC module in the car and direction indicators for parking guide. In this process, the vehicle and light module of celling exchange number of vehicle and ID of light. Thus, the smart parking lot system can guide the driver to the nearest empty parking space by using direction indicator based on location information of vehicles. The driver of vehicle can know the current position based on the received map information about parking lot. Figure 3 shows structure of process of finding a parking space.

2.3. Process of Parking Areas

In the parking area, the VLC module and break light of vehicle and VLC module in the celling, wall of parking area exchange vehicle information and current parking area position. Based on this information, smart parking lot system can be updated parking lot information and drivers can find the exact position of vehicle in the large parking lot later. Figure 4 shows the structure of parking area.

3. Experiments

Performance evaluation of various LEDs and the VLC reception ratio is performed through the experiments. A general low-cost MCU is used for transmitter and receiver.

During the experiments, we tested also performance according to various numbers of LEDs, and we tested data transmission and reception depending on the distance using selected LED and 13 LEDs. Receiving circuit was created as shown in Figure 5. Receiver receives the transmitted light from the transmitter using photo detector. Low Pass Filter (LPF) was applied to eliminate external noise and light from other light source. Cut-off frequency is about 800Hz. Cut-off frequency can be expressed as

$$\text{cut} - \text{off frequency} = 1/2\pi RC \qquad (1)$$

where R and C is resister and capacity, respectively.

Amplifier can amplify the received signal strength because received signal strength is very weak. Comparator receives the amplified signal when amplified signal is higher than the reference voltage. In this experiment, reference voltage is fixed about 1.1V, which is decided through the experiment. This reference voltage can reduce effects of noise during the reception signal received because less than the reference voltage is not considered to be received. Figure 6 shows transmitter and receiver.

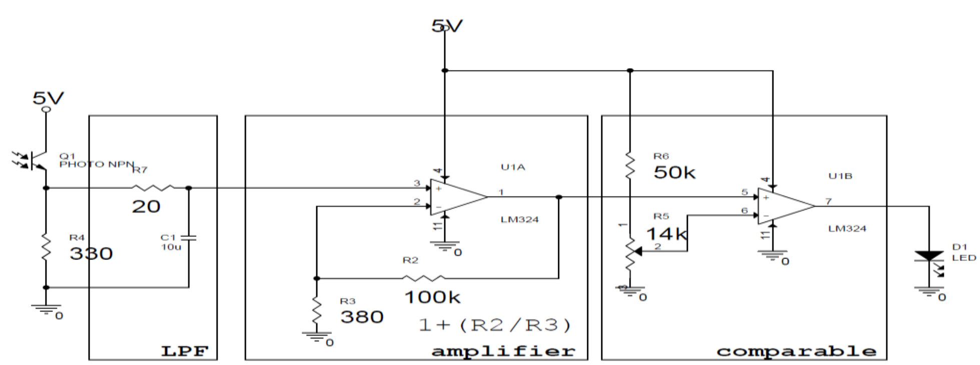

Figure 5. Receiving Circuit

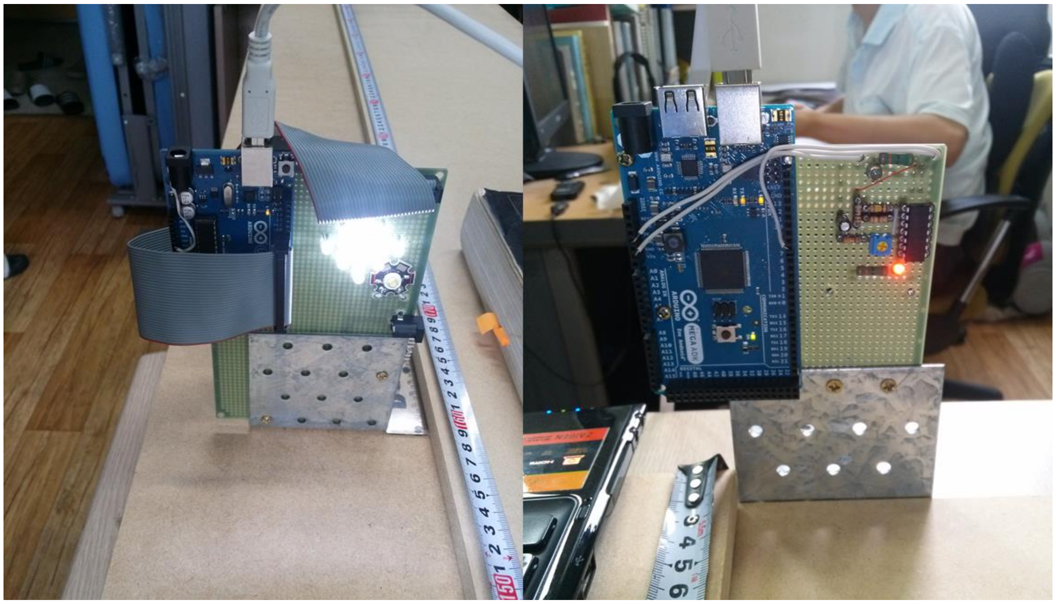

Figure 6. Transmitter and Receiver

3.1. Performance of various LED Type

We tested the receiving distance from transmitter to receiver. Tested results are summarized in Table 1.

Table 1. Performance Comparison of Various LEDs(Trial Time: 10)

	1.5m	2m	2.5m	3m	3.5m	4m	4.5m	5m
10ø white	10	10	10	10	0	0	0	0
10ø red	10	0	0	0	0	0	0	0
10ø blue	10	10	10	10	0	0	0	0
5ø brightness white	10	10	10	10	10	10	10	0
5ø brightness blue	10	10	10	10	0	0	0	0
Flux 5ø white	0	0	0	0	0	0	0	0
Flux 5ø red	0	0	0	0	0	0	0	0
Flux 5ø blue	0	0	0	0	0	0	0	0

Experiment is carried out in an environment that is almost light blocked to check the performance of the only LED. As shown in the table, the 5ø brightness white LED outperforms other LEDs of colors and types because the performance of 5ø brightness white

LED is higher than other LEDs. Even if specification of LED is different, we can know luminous and intensity angle of LED is very important element.

3.2. Performance of the Number of LEDs

We tested performance according to the number of LEDs, which are 5ø brightness white LED. Environment of experiment is shown in the Figure 7. Table 2 shows the results of experiment.

Table 2. Performance Comparison according to the Number of LED

	1m	1.5m	2m	2.5m	3m	3.5m	4m	4.5m	5m	5.5m	6m
1	O	O	1.89m	X	X	X	X	X	X	X	X
5	O	O	O	O	O	O	O	4.04m	X	X	X
9	O	O	O	O	O	O	O	O	O	5.24m	X
13	O	O	O	O	O	O	O	O	O	O	5.95m

As shown in the table, reception distance increases by increasing the number of LEDs. However, the relationship between the increase of the number of LEDs and the receiving distance was not linear.

3.3 Performance of data communication

There are digital encodings such as Non Return to Zero (NRZ), Return to Zero (RZ), Manchester encoding for data transmission. The LED can transmit data through on/off switching, and lighting should be turn on always. However, if transmitted data consists of a consecutive “0”, the light is turn off during data transfer.

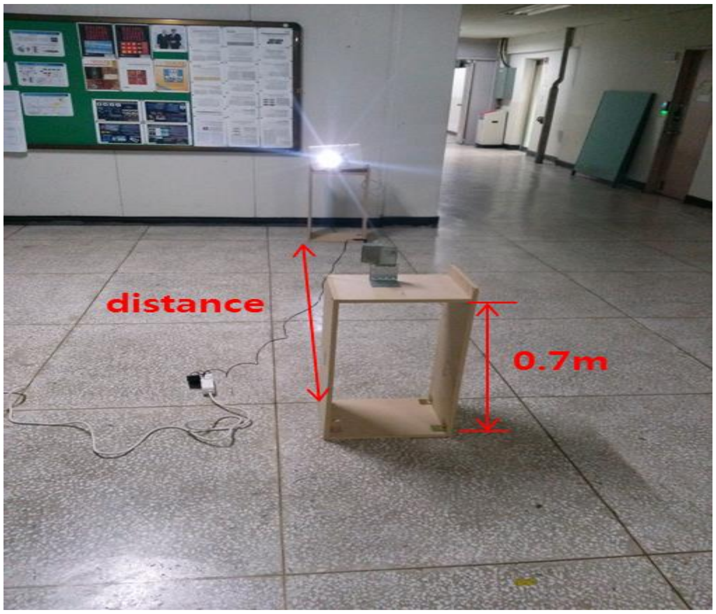

Figure 7. Experiment Environment

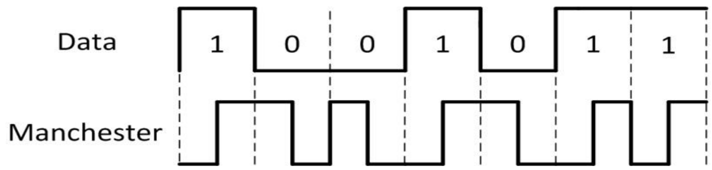

Figure 8. Example of Manchester Code

Therefore RZ and NRZ encoding is not suitable. Meanwhile, manchester encoding always can meet features of lighting because this method converts from one bit to two bits. Manchester coding is used in the 802.15.7 standard to ensure the period of positive pulses [11]. Figure 8 shows data converts of Manchester encoding, and it is applied in this experiment because synchronization is easier than other methods and error detection is possible.

The structure of the data bits were consisted of 5bits preamble (10001) and 16bit data. We decided preamble of 5bits because “0” or “1” cannot be repeated more than 3 times in the manchester codes, and character data of 8bits is converted 16bits data. And data rate of transmitter is 1KHz.

Receiver can restore original data through the Manchester decoding. Figure 9 show block diagram of VLC. We performed experiment of reception ratio according to difference distance with 13 LEDs. To check reception ratio, labview program is used. In the receiver, received signal convert char, and the MCU sends to Labview character by using serial communication. The transmitted character and the received characters are compared in the labview [12]. Figure 10 shows screen shot of Labview program.

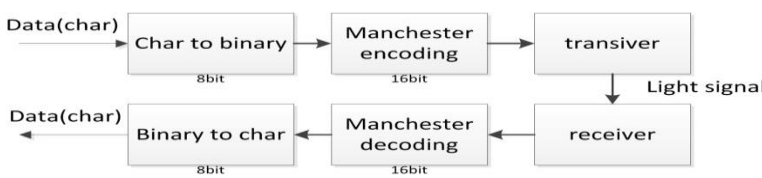

Figure 9. Block Diagram of VLC

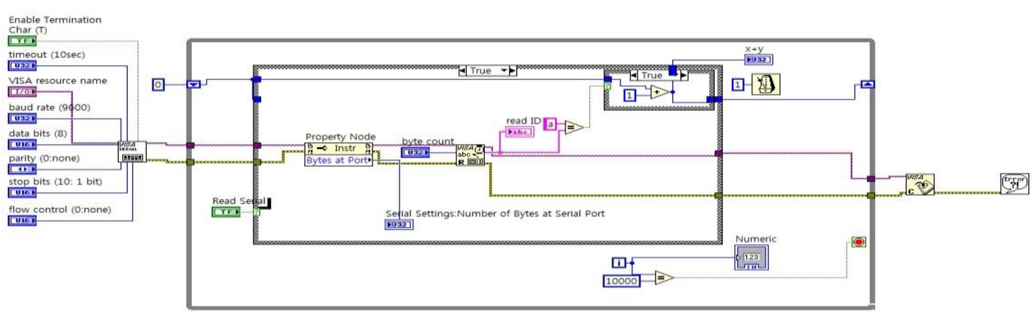

Figure 10. Labview Source for Data Comparison

Transmitter sends the character ‘a’ continuously, and the receiver receives data 10000 times after the preamble is matched. Figure 11 shows reception ratio.

As shown in the figure, reception ratio is about 80% until about 1.7m. However reception ratio is rapidly decreased after 1.7m. The increase of reception ratio in the 1.5m is expected effect of overlap of LED. Overlapping part is generated because of the position and intensity angle. To prove this phenomenon, additional experiments are needed.

By comparison with the results in Section 3.2, the relationship of reception of signal and data communication showed independence.

4. Discussion and Future Works

The performance of LEDs and communication is analyzed through experiments. The LEDs has a different luminance and intensity angle. Data transmission and reception distances are different depending on the number of LED. And LED performance should be also different depending on the position such as ceilings and walls. Therefore LED selection will be an important factor when implementing the system. The proposed smart parking lot system seems to be implemented based on the performed experiments of this paper.

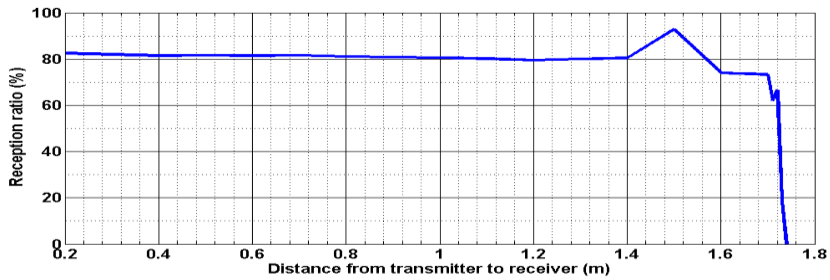

Figure 11. Reception Ratio

In this paper, basic experiment was performed for VLC. Experiments about Data reception ratio should be perform according to angle and distance for system implementation. Based on this research, the research about distance between lighting will proceed. And transfer of image and string is necessary for the implementation. Based on these studies, the proposed smart parking lot system will be implemented.

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References

[1] Z. Pala and N. Inanc, "Smart Parking Applications Using RFID Technology", RFID Eurasia, 2007 1st Annual, Istanbul, Turkey, **(2007)** September 5-6.

[2] J. Chinrungrueng, U. Sunantachaikul and S. Triamlumerd, "Smart Parking: An Application of Optical Wireless Sensor Network", Proceedings of the 2007 International Symposium on Applications and the Internet Workshops (SAINTW'07)0-7695-2757-4/07, Hiroshima, Japan, **(2007)** January.

[3] 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", International Conference on Advanced Information Networking and Applications Workshops, Bradford, England, **(2009)** May, pp. 26-29.

[4] G. Pang, T. Kwan, H. Liu and C.-ho Chan, "Industry Applications Magazine, IEEE, vol. 8, no. 1, **(2002)**.

[5] W. Rui, D. Jing-yuan, S. an-cun, W. Yong-jie and L. Yu-liang, "Indoor optical wireless communication system utilizing white LED lights", Proceeding of the 15th Asia-Pacific Conference on Communications, Shanghai, China, **(2009)** October 8-10.

[6] K. Lee, D. Cha and K. Lee, International Journal of Control and Automation, vol. 6, no. 2, **(2013)**.

[7] J. Kang, K. Um, S. Yoo, G. Choi, Y. Im, S. Park and E. Kang, International Journal of Control and Automation, vol. 6, no. 2, **(2013)**.
[8] X. Ma, K. Lee and K. Lee, Editors. Electronics Letters, vol. 48, no. 18, **(2012)**.
[9] J. P. Ding and Y. F. Ji, Editors. Optoelectronics, IET, vol. 6, no. 6, **(2012)**.
[10] T. Komine, J. H. Lee, S. Haruyama and M. Nakagawa, "Wireless Communications", IEEE Transactions on, vol. 8, no. 6, **(2009)**.
[11] S. Rajagopal, R. D. Roberts and S. K. Lim, "Communications Magazine", IEEE, vol. 3, no. 50, **(2012)**.
[12] R. W. Larsen, "LabVIEW for Engineers", Prentice Hall Publishers, New Jersey, **(2011)**.

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