15x15 Kernel Block Adaptive Median Filter를 적용한 저속 카메라 통신용 LED 조명 검출 알고리즘 연구

15x15 Kernel Block Adaptive Median Filter based on LED Illumination Detection Algorithm for Low Rate CamCom

한 정 도* · 이 민 우** · 차 재 상***

* 주저자 : 서울과학기술대학교 IT융합공학과 석사과정
** 공저자 : 서울과학기술대학교 IoT융복합기술연구소 연구원
*** 교신저자 : 서울과학기술대학교 전자IT미디어공학과 교수

Jungdo Han* · Minwoo Lee** · Jae Sang Cha***

* Dept. of Integrated IT Eng., Seoul National Univ. of Science and Tech
** IoT Convergence Research Technology Lab., Seoul National Univ. of Science and Tech
*** Dept. of Electronics and IT Media Eng., Seoul National Univ. of Science and Tech
† Corresponding author : Jae Sang Cha, chajs@seoultech.ac.kr

Vol.17 No.5(2018)
October, 2018
pp.143~150

ISSN 1738-0774(Print)
ISSN 2384-1729(On-line)
https://doi.org/10.12815/kits.2018.17.5.143

Received 1 October 2018
Revised 15 October 2018
Accepted 16 October 2018

요　약

RF 기반 고속 무선통신 기술이 급속히 발전함에 따라 무선 주파수 대역을 기반으로한 IoT 네트워크용 디바이스가 빠르게 보급되고 있으나, 최근 IoT 네트워크 디바이스의 급속한 확산속도에 비하여 RF 통신 기술의 발전속도가 미치지 못하고 있다. 이러한 상황에서 가시광원을 송신수단으로 사용하는 OWC 기술은 RF 기반 무선 통신의 대역 고갈 문제를 극복 할 수 있는 기술로서 주목받고 있으나, OWC용 데이터 수신 중 발생하는 LED 조명 형태의 왜곡으로 인하여 LED 조명 검출율이 저하되고 RoI의 설정이 부정확해지는 현상이 발생 할 가능성이 있다. 본 논문에서는 Adaptive Median Filter를 적용한 저속 카메라 통신용 LED 조명 검출 알고리즘을 제안하였다. 이를 통해 명확한 RoI 설정 및 LED 조명 검출이 가능할 것으로 사료되며, 본 연구 결과를 통해 RF 기반 무선 통신기술의 보완재로서의 역할을 효율적으로 수행 할 수 있을 것으로 판단된다.

핵심어 : 광무선통신, 광카메라통신, 저속 카메라 통신, Adaptive Median Filter

ABSTRACT

With the rapid development of RF based high speed wireless communication technology, devices that can be applied to IoT networks based on RF bandwidth are rapidly spreading, nevertheless, the development speed of the RF communication is not possible to keep up with the spread of the RF band for wireless communication. In this situation, OWC technology that uses visible light source as a transmitter is attracting attention as a technology that can overcome the band exhaustion problem of RF based wireless communication technology. Although, due to the distortion of the LED illumination shape by camera exposure time and LED blinking period, the LED illumination detection rate is degraded and the RoI setting is inaccurate. In this paper, we propose an adaptive median filter applied LED illumination detection algorithm for low rate CamCom, it is possible to detect a clear RoI and LED illumination. This research will be able to play a role as a complementary material of RF based wireless communication technology efficiently.

Key words : Optical Wireless Communication, Optical Camera Communication, Low Rate CamCom, Adaptive Median Filter,

Ⅰ. Introduction

With the development of RF based wireless communication technology including Wi-Fi and Bluetooth, it is equipped with RF communication module in various fields such as cellular phone, smart watch, home appliance as well as RF communication device for existing internet network. Although the RF band used by the product equipped with the RF communication module has different center frequency, the band is expected to be depleted due to the rapid consumption of the RF band. Various solutions such as expansion to the high frequency band have been studied, but no clear solution was provided(Ghassemlooy, 2015).

OWC(Optical Wireless Communication) technology using a visible light source for a transmitting medium is attracting attention as a technology that can overcome the limitations of such RF based wireless communication technology. The OWC technology can be classified into a receiving method using a photodetector for converts visible light emitted from an LED into an electric signal and a receiving method that using a camera image sensor to recognize visible light data of an LED and display. Among them, the visible light receiving technique using the camera image sensor is called OCC(Optical Camera Communication), and the standardization work is under way in the IEEE802.15.7r1 Task Group. Currently, most people use cameras in smart phones and tablets, which are commonly used in everyday life, and OCC have excellent usability because they do not require additional infrastructure and can utilize widely used equipment(Chow, 2015).

On the other hand, the OCC technique using LED illumination is advantageous in that a camera of a smart device, which is widely used, can be used as a receiver. However, according to the blinking period of the transmitting side LED illumination and the camera exposure time of the receiving side, the shape and boundary of the LED illumination displayed on the image frame acquired by the receiving side camera are distorted, and the detection rate of the LED illumination is decreased.

In this paper, we propose an adaptive median filter which corrects distortion of LED illumination in image frames and improves LED illumination detection rate and RoI setting. This can improve the variety of OCC data reception technology between LED illumination and camera distance, LED blink time and camera exposure time.

The order of this paper is as follows: At first, discuss about the background of this study. In Section 2, the background of prior research analysis and research on OCC based OWC technology and image processing based image filtering technology is established. In Section 3, we propose an LED illumination detection algorithm using an adaptive median filter. In Section 4, we verify the proposed algorithm. Finally, in Section 5, we conclude this paper.

Ⅱ. Related Work

Bilateral filter, gaussian filter and median filter which are used for image shape and distortion correction and noise reduction. These filters are common in that the pixel values of the image to which the filter is applied are determined through the weight calculation of the input pixel values.

The gaussian filter is designed based on the characteristics of image that relatively slow spatial changes. The center pixel value to which the filter is applied is replaced by the weighted average value of adjacent pixel values. The correlation between noise and adjacent pixel values is relatively small, and the weighted average value of adjacent pixel values can be relaxed. However, the boundary is blurred because the image is vulnerable to an abrupt change in the pixel value, such as the boundary within the image. This can be a disadvantage and an advantage depending on the user's intention

The bilateral filter is a complementary method to the gaussian filter which does not preserve the boundary. It has a nonlinear based operation characteristic unlike the popular filter. Similar to the gaussian filter, the filter applied value of each pixel is replaced by the weighted average of adjacent pixel values. However, not only the distance between the center pixel value and the adjacent pixel value but also the difference value of the pixel value itself is also reflected in the weight(Elad, 2002).

The median filter replaces the center pixel value with the median value of neighboring pixel values and has a simple operation structure to expect fast operation speed. Unlike the gaussian filter and the bilateral filter, the detailed shape is preserved and the highest weighted intermediate value is used instead of the average value of the pixel values in the kernel window. This feature shows excellent performance in removing noise, but it has a disadvantage in that it is difficult to distinguish the detailed feature region and the noise value. The adaptive median filter is a method to compensate the disadvantage of the median filter. The adaptive median filter compares the noise value with the pixel value existing in the kernel window to distinguish the intended feature region. Adaptive median filters can effectively work on noise reduction, distortion and shape correction in image frames of LED illumination detection process during OCC method(Hwang, 1995).

The OCC technique using LED illumination receives the visible light data from the LED illumination using the characteristics of the rolling shutter technique in which the output image is deformed according to the exposure time.

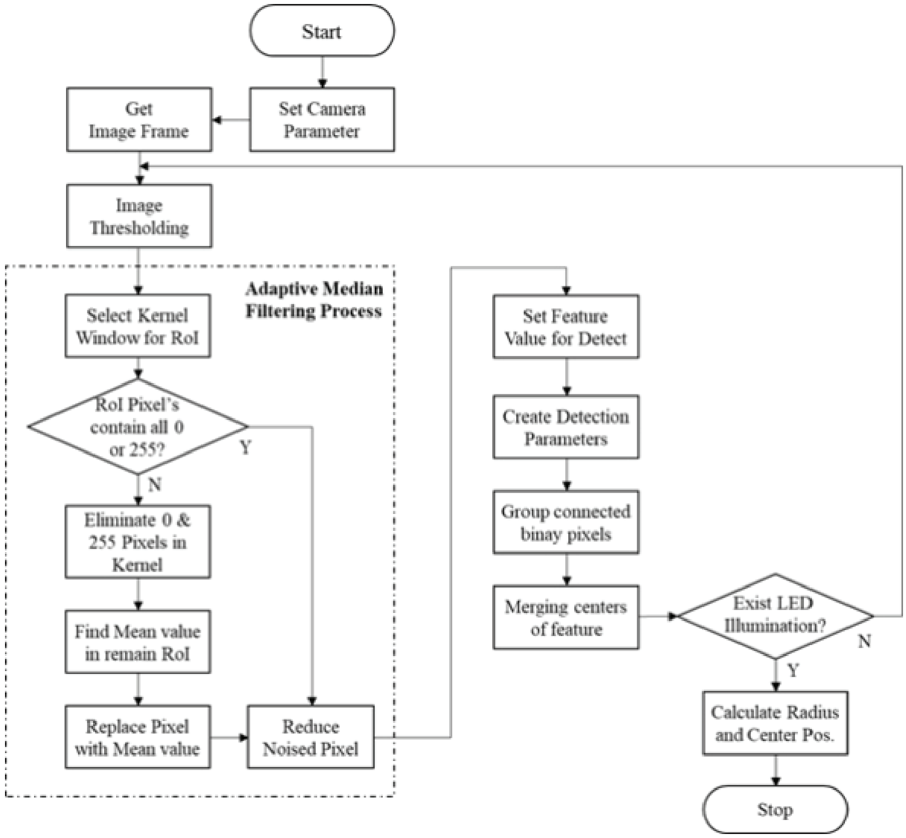
Generally, when the LED blinks at a cycle of at least 200 Hz, only a change in the overall illuminance occurs, and it is impossible to visually discriminate whether the LED illumination is blinking or not. At this time, in the output image that receives the visible light data from the LED illumination, the white line and the black line are represented according to the blinking period of the LED illumination, and different information can be mapped(Cha, 2018).

By adjusting the exposure time of the camera, the overall brightness of the image is minimized, only the LED illumination area is recognized, and bit mapping can be applied due to the brightness difference between the lines due to the blinking of the LED illumination (Mariappan, 2018).

However, when the OCC receiving method using the LED illumination is applied, the shape of the LED illumination formed on the image frame is distorted depending on the distance between the camera and the LED illumination, the blinking period of the LED illumination, and the camera exposure time. This leads to a problem that the LED illumination detection rate is lowered and the RoI setting cannot be made definite. In the previous research, it is proposed a solution to solve this problem by using a change of data decoding method or camera zoom(Y. Chae, 2017). In this paper, we propose a solution for improve LED illumination detection rate using an 15x15 kernel block adaptive median filter applied LED illumination detection algorithm.

Ⅲ. 15x15 Kernel block adaptive median filter applied LED illumination detection algorithm

In this study, we applied adaptive median filtering processing in the previous step of LED illumination detection process when applying OCC receiving method using LED illumination, and proposed an algorithm to correct shape distortion of LED illumination according to LED blinking cycle and camera exposure time.



<Fig. 1> Adaptive median filter applied LED illumination detection algorithm

In there adaptive median filtering process in the LED illumination detection algorithm, first determines the size of the kernel window to be applied to the image frame. After determining whether the pixels in the kernel window are binarized, remove the 0 and 255 bits, calculate the average value in the kernel window, replace the pixel value in the kernel window with the average value, and proceed with noise removal. The LED illumination detection technique is then applied to determine the presence or absence of an LED illumination in the image frame. When the LED illumination is detected through the application of the LED illumination detection technique, the center coordinate value of the LED illumination is extracted and the RoI for data decoding is set around the coordinate value. And then, the row pixels of RoI are scanned to determine the presence or absence of a data header. When a data header is detected, data decoding is performed.

The adaptive median filter is applied to correct the shape of the LED illumination, remove the noise pixels, improve the detection rate of the LED illumination, and set a clear RoI for data decoding. The verification of the designed algorithm applied adaptive median filter was carried out in section 4.

Ⅳ. Implementation and analysis

In order to verify the effectiveness of the proposed 15x15 kernel block adaptive median filter based OCC receiving algorithm, we conducted LED illumination detection experiment that sends OCC data. The adaptive median filter is applied to the image after applying the variable binarization technique during LED illumination detection algorithm. We compared the detection of the LED illumination with the adaptive median filtering process applied result and the non-filter applied result, and the experimental environment that we constructed to verify the proposed algorithm is as follows:

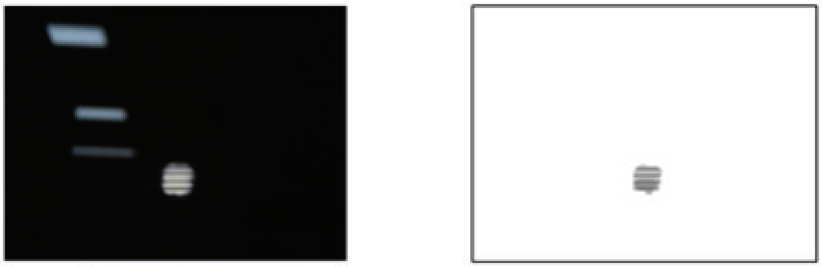
<Table 1> Evaluation Conditions of Experiment

Evaluation Conditions	
Diameter of LED Illumination	78 mm
Distance between Tx and Rx	1 m
Blinking Period of LED Illumination	833 microseconds
Modulation Method	OOK with Manchester Coding
Receiver Camera Module	Microsoft Lifecam Studio

<Fig. 2> Experimental environment

<Table 1> shows the experimental conditions set for the verification of the illumination detection algorithm based on the adaptive median filter. The diameter of the LED illumination used is 78mm, and the size of the indoor and outdoor illumination is selected. The distance between the LED illumination used as the transmitter and the camera used as the receiver is set to 1m. The blinking period of the LED is 833 microseconds, and the blinking of the illumination is not identified to the naked eye. At the same time, the data transmission at the proper speed is enabled, and the manchester coding based OOK technique is applied to minimize the fluctuation of the brightness by the blinking.

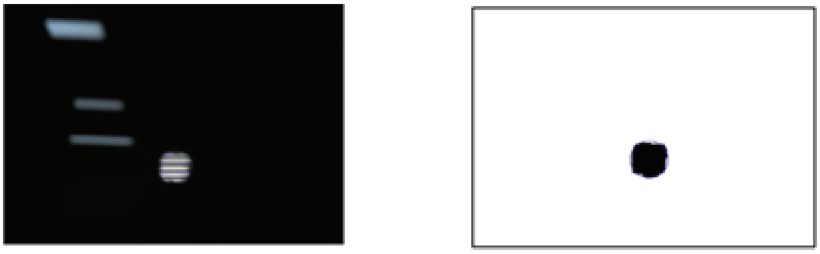
<Fig. 2> shows the experimental environment based on the experimental conditions. The efficiency of the illumination detection algorithm based on the adaptive median filter is as follows.



(a) Original Image (b) Non-filter applied

<Fig. 3> Original image and non-filter applied result

In <Fig. 3-(a)> shows the original image obtained by the camera during the detection of LED illumination. (b) shows only the application of grayscale conversion and image thresholding. It can be seen that LED illumination can not be detected even though it exists within the angle of view of the camera.



(a) Original Image (b) Adaptive Median Filter applied

<Fig. 4> Original image and adaptive median filter applied result

In <Fig. 4-(a)> is the original image taken in the same environment as <Fig. 3-(a)>, <Fig. 4-(b)> is the result of applying the adaptive median filter after the grayscale conversion and image thresholding process. In contrast to <Fig. 3-(b)>, the boundary between the black line and the white line does not appear in the blinking of the LED illumination, and LED illumination detection for entering the OCC data decoding process proceeds normally.

As a result of the verification of the 15x15 kernel block adaptive median filter applied LED illumination detection algorithm, when the camera and the LED illumination are not close to each other, the detection rate of the LED illumination is lowered Respectively. On the other hand, in the image frame acquired through the adaptive median filtering process, the shape of the LED illumination is corrected and the noise pixels are reduced even when the camera exposure time and the blinking period of the LED illumination are changed. It is confirmed that the is detected to improve the detection rate of the LED illumination and to set a clear RoI for the OCC data decoding.

In addition to the adaptive median filter applied algorithmm in this paper, we can apply various image processing techniques to improve the detection rate of LED illumination without changing the camera shutter speed. Also, it is possible to obtain a shape similar to that of LED illumination by correcting the distortion of the image caused by blinking of the LED illumination through a correction technique such as dilate rather than a filter technique.

Ⅴ. Conclusion

In this paper, we propose a method to improve the detection rate of LED illumination and to set a clear RoI by applying the 15x15 kernel block adaptive median filter applied LED illumination detection algorithm.

Because of the shape of the LED illumination is distorted on the image frame according to the exposure time of the camera and the LED blinking period, the conventional LED based OCC reception method has the problems that the LED illumination detection rate is decreased and the RoI is set incorrectly.

In this paper, we propose and validate a technique to improve the detection rate of LED illumination and to set a clear RoI through the adaptive median filter applied LED illumination detection algorithm for low rate CamCom in IEEE802.15.7r1. Based on the results of this research, it is possible to improve the detection rate of LED illumination when applying LED based OCC technique using smart device camera and webcam in the future. Also, it can be applied at longer distance compared to existing technology, it can be used effectively as a complementary material to supplement the shortcomings of the RF based wireless communication technique in the future.

ACKNOWLEDGEMENTS

This work was supported by Institute for Information & Communication Technology Promotion(IITP) grant funded by the Korea government (MSIP), (No.2017-0-00218, International Standardization Research of VLC Application Technology based LiFi and CamCom).

REFERENCES

Cha J. S. and Mariappan V.(2018), “LED-ID Technology for IEEE802.15.7m OWC,” *IEEE COMSOC MMTC E-Letter*, vol. 13, no. 3, pp.29-33.

Chae Y. S. *et al*.(2017), “Smartphone-based Image Sensor Communication Using Digial Zoom,” *in Proc. Symposium of the Korean Institute of Communications and Information Sciences*, pp.277-278.

Chow C. W. *et al*.(2015), “Enhancement of signal performance in LED visible light communications using mobile phone camera,” *IEEE Photonics Journal*, vol. 7, no. 5, pp.1-7.

Elad M.(2002), “On the origin of the bilateral filter and ways to improve it,” *IEEE Transactions on image processing*, vol. 11, no. 10, pp.1141-1151.

Ghassemlooy Z. *et al*.(2015), “Emerging Optical Wireless Communications-Advances and Challenges,” *IEEE Journal on Selected Areas in Communications*, pp.1738-1749.

Hwang H. and Haddad R. A.(1995), “Adaptive median filters: new algorithms and results,” *IEEE Transactions on image processing*, vol. 4, no. 4, pp.499-502.

Mariappan V. *et al*.(2018), “OWC based Smart TV Remote Controller Design Using Flashlight,” *International Journal of Internet, Broadcasting and Communication*, vol. 10, no. 2, pp.71-76.