High Speed Parallel Transmission Visible Light Communication Method with Multiple LED Matrix Image Processing Technique

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Abstract— In this paper, we have studied a multi - LED matrix optical sensing technology for high speed transmission in a visible light communication system based on an optical camera CCD sensor. In order to improve transmission capacity in visible light communication, data must be transmitted from different LEDs at the same time and received. However, a system environment with multiple LEDs may cause interference between adjacent LEDs. Generally, since a visible light communication system generally uses a luminance modulation method, when a plurality of LEDs transmit data at the same time, it is difficult to accurately detect each LED due to light scattering interference of an adjacent LED. To solve this problem, we proposed a spatial filtering technique to group multiple LEDs and to reduce the interference of grouped LED matrix. We also propose a pixel image processing technique for detecting each LED. This technology accurately recognizes each matrix of LEDs in a multi-matrix LED environment and improves system performance by increasing the throughput of the MISO-OCVLC (Optical Camera Visible Light Communication) system.

Keywords— Optical wireless communication, Visible light communication, MISO-OCVLC, LED matrix parallel transmission, Optical camera

I. INTRODUCTION

Convergence technologies such as IoT and ICT are attracting attention as the keyword of the fourth industrial revolution recently appears. The emergence and development of this fourth industry is also affecting wireless communication systems. In existing wireless communication systems, LED-based visible light communication systems have been actively studied. LED-based visible light communication system is a system that transmits data based on visible light emitted from LED. A study on the wireless network environment using LED lighting has been under way [1]. It also eliminates the need for frequency licensing, does not interfere with the Industrial Scientific Medical band (ISM) band, and provides physically high levels of security. The optical bandwidth (THz) of the LED light source is the next generation wireless communication system that many companies are interested in because it can transmit high-speed data compared to existing RF communication. In this paper, we have studied a technique for implementing MISO parallel transmission system for high speed visible light communication. In the conventional PD method, parallel data transmission using plurality of light sources is difficult due to a problem of interference between light sources. Therefore, in this paper, a visible light communication system based on optical camera CCD sensor is used. Visible light communications can be subject to a variety of interference, such as sunlight and other light sources. Therefore, accurate channel modeling, adaptive coding and modulation schemes, synchronization schemes, channel estimation and allocation are needed. Also, in an environment where a large number of LEDs exist, signal detection and estimation are difficult due to inter-LED interference. Therefore, efficient signal detection and estimation methods are needed. Since a visible light communication system generally uses a luminance modulation method, it is difficult to accurately detect each LED due to optical diffusion interference of adjacent LEDs when a plurality of LEDs transmit data at the same time. To solve this problem, we proposed a spatial filtering technique to group multiple LEDs and to reduce the interference of grouped LED matrix. We also propose a pixel image processing technique for detecting each LED. Conducting a convolution operation with a specific mask on the LED matrix group, the inter-LED group interference is controlled by spatial filtering, which clearly shows the edge or contour of the matrix. In addition, LED spectrum estimation method using correlation coefficient accurately recognizes ON / OFF of LED pixel in each matrix, and improves total average bit error rate and throughput of MISO-VLC system[2]. Through this multi-LED parallel transmission scheme, a MISO-VLC high-speed transmission system can be realized.

II. SYSTEM MODEL

In an optical communication system which is difficult to realize an economical coherent communication system due to a high frequency, it is possible to use an intensity intensification (IM) method of a light source and a direct intensity detection method using a light detection diode (DD) Demodulate. The intensity modulation / direct detection (IM / DD) method has been widely applied to wired optical communication devices for backbone and access networks, and element technologies for drivers, light sources, modulators, optical detectors and first stage amplifiers are widely commercialized, The most economical system configuration is possible. Therefore, the IM / DD (IM / DD) method is a modulation / demodulation method which is considered in the optical wireless communication system aiming at high performance and low price system. The transmission method of visible light wireless communication according to the intensity modulation / direct detection (IM / DD) is as follows. The output variable Y (t) is the convolution of the channel impulse response h (t) and p (t), where X (t) is the optical power of the transmission signal and Y (t) The noise current n (t) is summed and the physical unit is the current. Where p (t) is the power of the optical power, so Watt, n (t) is Ampere, and h (t) is Ampere / Watt. The optical channel X (t) should have the condition X (t) ≥0, which is a channel input non-negative, which is the same as the transfer function model of a general linear system. Therefore, the transmission characteristics of the optical modulator / demodulator can be expressed as a baseband equivalent channel model as follows.

$$\mathrm{Y}(t) = \gamma X(t) * h(\mathrm{t}) + \mathrm{N(t)}$$

$\mathrm{Y}(t)$ denotes a received signal, and $X(t)$ denotes a transmitted optical pulse signal. N(t) denotes AWGN, ∗ denotes a convolutional code, and γ denotes an optical / electrical (O / E) conversion efficiency value.

The channel impulse response can be expressed as:

$$G(t;S,D) = \sum_{k=1}^{\infty} G^{k}(t;S,D)$$

Here, $G^{k}(t)$ represents the impulse response of the signal that is reflected k times. The high-order terms of the channel impulse response considering the LOS signal are expressed as follows.

$$G(t;S,D) = \int G^{(0)}(t;S,\{r,n,\frac{\pi}{2},dr^{2}\} * \mathrm{G}^{(k-1)}(t;\{r,n,1\},D)$$

Here, r represents the position vector on all the reflection surfaces S. n represents the unit normal vector at the position r in the reflection plane S, and dr^{2} is the diffraction plane at the position r of the reflection surface [3-5].

III. THE INTERFERENCE MODEL OF THE PROPOSED SYSTEM

Figure 1 shows the LED matrix group. Each matrix consists of LED pixels in an m * m matrix, and each matrix consists of an array. The LEDs in each matrix transmit different data simultaneously at wavelengths between 700nm and 380nm. The receiver consists of an optical camera image sensor and simultaneously reads and processes the pixel LEDs of the m * m matrix. In this environment, adjacent LEDs cause interference due to the diffusion of light. The LEDs between adjacent pixels are subject to light interference between the two LEDs, preventing the image sensor from reading the correct data. In addition, such overlap area interference causes distortion such as misalignment, perspective distortion, blurring, and vignetting. Visible light communications based on image sensors are vulnerable to this interference. Also, in order to increase the transmission capacity, each LED matrix group in Fig. 1 must be accurately recognized.

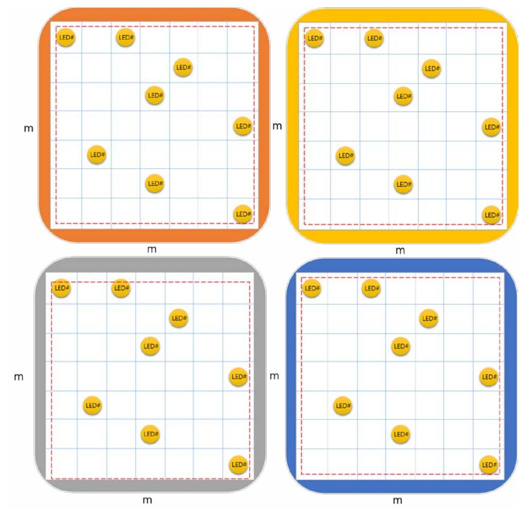

Figure. 1 LED array model of m*m matrix

IV. OPTICAL INTERFERENCE CANCELLATION IN HIGH SPEED TRANSMISSION MISO-OCVLC

In a conventional PD-based visible light communication, when a plurality of LEDs are used, it is difficult to implement the system due to inter-LED interference. In the method using an image sensor, such a problem can be solved and data can be simultaneously received from a plurality of LEDs.

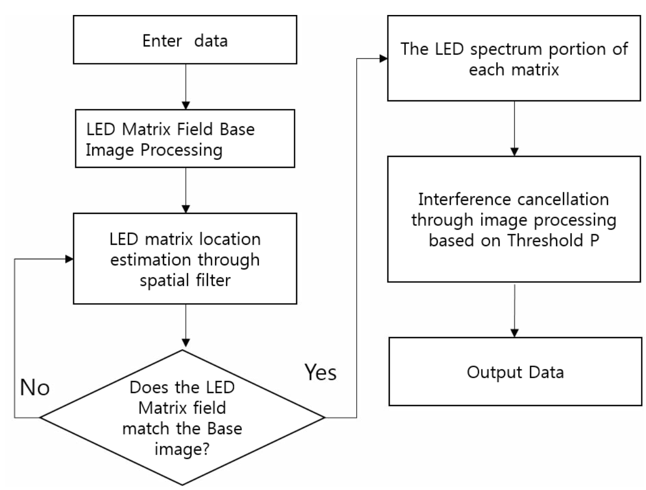

Figure. 2 System flow chart

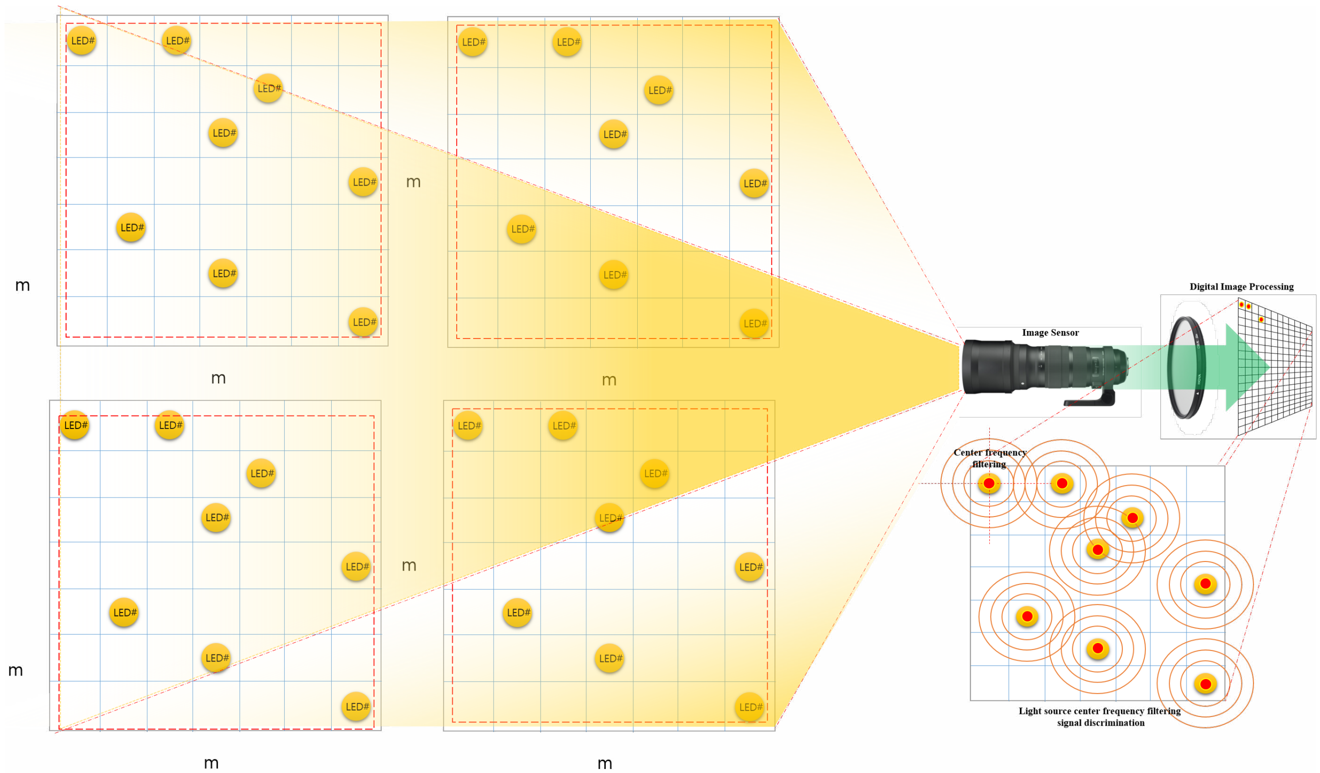

Figure. 3 Proposed System Model Structure

However, existing systems focus only on single link modeling. To realize high-speed transmission, a simultaneous transmission system through a plurality of LEDs is required. For this purpose, when multiple LEDs transmit data at the same time, it is necessary to remove the light scattering interference of adjacent LEDs to accurately detect each LED, and to effectively control many LEDs. In this paper, we propose a spatial filtering method to accurately recognize each matrix group. Figure 2 shows the system flow chart. A method of determining the values of pixels by convoluting a video signal with a specific mask through a filter in a spatial domain. The response of a linear filter with mask-based processing is g (x) 5 = $x_1h_1 + x_2h_2 + \dots + x_8h_8 + x_9h_9$ and the result is stored in the center position. Mask is the basic mask of low-pass filter. The sum of each pixel is set to be 1. This is used to clearly show the edge or contour of the still image. The autocorrelation coefficient is measured based on the center frequency of the spectrum of the unique wavelength band of each LED, and this is called a Threshold P. On the basis of this Threshold P, the light source received by the image sensor compares with the threshold value P through pixel image processing. On the receiving side, since the center point of the LED is correctly recognized as ON only when the center point of the LED is higher than the Threshold P, optical interference among a plurality of light sources can be completely prevented.

We applied grayscale for effective image processing. Grayscale is an image represented by a gray color of black and white. It is based on the intensity of light and is expressed in black (0) and white (255) in 256 steps from 0 to 255 and the intermediate gray level is 128. In order to shorten the time required for template matching required for analysis, Base, ON, and OFF images were grayscale processed.

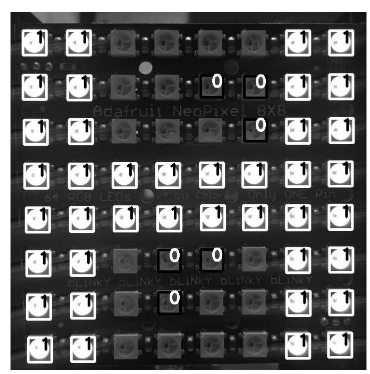

Figure. 4 m * m LED Matrix Image Processing with Grayscale & Template Matching

The pattern analysis that is directly related to communication performance uses Template Matching. This matching method searches for a matching position with the template image in the reference image. In general, Template Matching can use the brightness of the image as it is, but undergoes a normalization process in order to less affect the light intensity during processing. Edge, frequency conversion, etc., and perform matching. There are six types of matching methods, including normalization methods. Among them, correlation coefficient method was used. The correlation coefficient method performs matching based on the average of each template and input image. Returns 1 if there is a perfect match, -1 if there is a complete discrepancy, and 0 if there is no association between the two images. Because it has the largest amount of computation compared to other methods, it shows the detection result of the most accurate form although the matching speed is slow [6]. Figure 4 shows the image processing with Grayscale & Template Matching applied.

V. PERFORMANCE EVALUATION

We implemented LED matrix to implement parallel transmission system. The LED matrix used in the test-bed were each composed of 8 × 8 Matrix. In addition, the receiver uses image processing technology using a camera composed of a CCD image sensor. The data received through the image sensor is first applied to grayscale. This can improve overall throughput. After applying the proposed image processing to each LED matrix, we applied Template Matching.

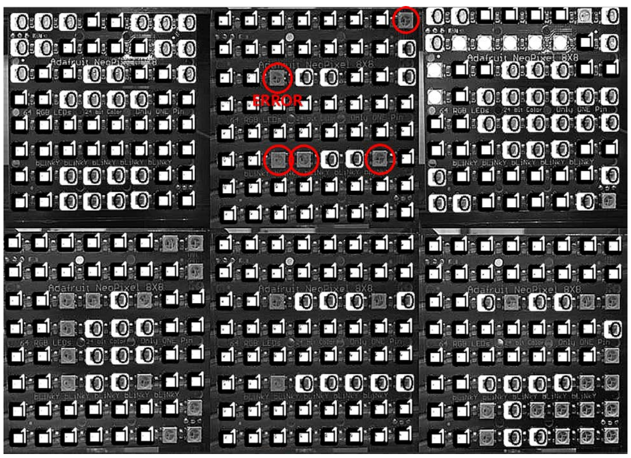

Figure. 5 Six 8X8 LED Matrix Recognition Image (Alphabet A, B, C, D, E, F)

Figure 5 shows the received signal image with the proposed method. The test bed implements parallel transmission using six LED matrices. Each matrix transmits data by repeating ON / OFF in alphabetical form of A, B, C, D, E, and F. The signal received by the image sensor is compared with a threshold value P measured based on the center frequency of each LED spectrum. On the receiving side, since the center point of the LED is correctly recognized as ON only when the center point of the LED is higher than the threshold value P, the optical interference between the plural light sources can be eliminated. The 8X8 matrix on the upper left of the figure shows that the LED pattern that is transmitting the data in the form of alphabet A is precisely classified. However, when we look at the remaining alphabet B-F LED matrix, the ON pattern is recognized correctly, but it does not recognize correctly in some of OFF pattern. This is a problem caused by a long focal length for recognizing an entire array matrix in a CCD image sensor when a plurality of LED matrices are configured as an array. As the focal length became longer, the recognition rate decreased because each LED pixel appeared small. This problem will be improved through future research.

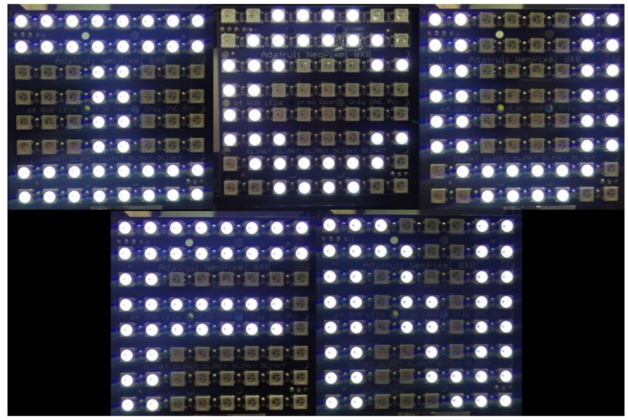

Figure. 6 Five 8X8 LED Matrix (Alphabet I,C,U,F,N)

Figure 6 shows a test bed consisting of five 8X8 LED matrices, each of which was turned on and off in the form of an I,C,U,F,N alphabet.

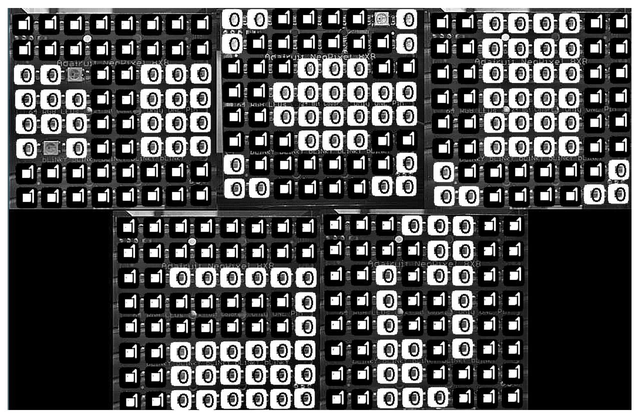

Figure. 7 Five 8X8 LED Matrix Recognition Image (Alphabet I,C,U,F,N)

As shown in the figure 7, it can be seen that correct LED ON / OFF pattern is recognized by removing the light source due to interference of adjacent LEDs. Through the proposed method, interference between each light source is effectively eliminated in a parallel transmission system composed of a plurality of LED matrices, so that accurate data transmission and reception can be achieved. Thus, it is possible to solve the interference problem caused by realizing high-speed visible light communication. However, in the first matrix I pattern, two OFF pixels were not correctly recognized. As mentioned above, there is a problem for the focal length, and a method for improving the recognition rate is needed.

VI. CONCLUSION

In this paper, we have studied a multi - LED matrix optical sensing technology for high speed transmission in a visible light communication system based on an optical camera CCD sensor. An image processing technique is applied to eliminate the optical dispersion interference of adjacent LEDs generated when LEDs transmit data at the same time, thereby realizing correct ON / OFF matching recognition. Through the proposed scheme, the performance of the overall system can be improved by controlling the interference of the LED parallel concurrent transmission. However, as the number of LED matrices increases, the image processing time increases and the efficiency of the entire system decreases. Research on image processing technology to overcome this problem should be carried out. We expect to be able to provide services that satisfy the QoS of the entire system by improving the image processing time of the LED matrix through further research.

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