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시각 셀 OOK 변조 : MIMO CamCom 연구 사례

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Visual Cell OOK Modulation: A Case Study of MIMO CamCom

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ABSTRACT

Multiplexing information over parallel data channels based on RF MIMO concept is possible to achieve considerable data rates over large transmission ranges with just a single transmitting element. Visual multiplexing MIMO techniques will send independent streams of bits using the multiple elements of the light transmitter array and recording over a group of camera pixels can further enhance the data rates. The proposed system is a combination of the reliance on computer vision algorithms for tracking and OOK cell frame modulation. LED array are controlled to transmit message in the form of digital information using ON-OFF signaling with ON-OFF pulses (ON = bit 1, OFF = bit 0). A camera captures image frames of the array which are then individually processed and sequentially decoded to retrieve data. To demodulated data transmission, a motion tracking algorithm is implemented in OpenCV (Open source Computer Vision library) to classify the transmission pattern. One of the most advantages of proposed architecture is Computer Vision (CV) based image analysis techniques which can be used to spatially separate signals and remove interferences from ambient light. It will be the future challenges and opportunities for mobile communication networking research.

Key Words : OOK, Computer Vision, VLC, CamCom, MIMO

Ⅰ. Introduction

Camera based communication system is a highly directional transmission system by using the optical channel, which is different from traditional RF channel. The directional transmission advantage can provide potential safety advantages and special environment. The increasing installation rate of camera in cell phone has created a big opportunity to build a camera based communication system, since almost every smart phone has a high pixel build-in camera. It will be promising future direction which combines illumination and communication. Especially, in line of sight marketing service and indoor localization application [1]. By combining the illumination and small amount of data (html link) for broadcasting or finding direction in indoor application, CamCom which can be extended from all current smart phone, will be a promising service. Different from

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other visible light communication [2] methods proposed in the previous research, smart phone camera based communication is an almost no additional cost technology by taking the advantage of build-in camera in smart phone. Although the frame rate of smart phone camera is fixed to 30 fps, the pixels of our smart phone are increasing as the demand of the market.

In this paper we will detail how MIMO techniques based on LED array for transmission and camera image sensor for receiver. By the individual pixel elements of the camera the proposed model act as multiple receive elements to create the visual MIMO channel. The pixels in a camera can essentially be viewed as an array of highly directional received elements. Such a system offers a degree of freedom in selecting and combining a subset of the receiver elements that receive a strong signal from the transmitter and thus achieve large SNRs. This may be very similar to the antenna selection in RF-MIMO but will incur lesser overhead and non-complex processing at the camera receiver as the processing can be done in software using image processing and computer vision algorithms. The use of Computer Vision algorithms also helps to locate the LED transmitter in the presence of background distracters. Recall that the primary advantage of the visual MIMO channel over standard communication channels is the ability to focus attention at the correct portion of the scene.

The remaining of paper is structured as follows. The overview proposed model of visual Cell OOK (VCO) for MIMO CamCom will be presented in section 2. The performance analysis is presented in section 3. Section 4 concludes remarks of the research results and contributions.

Ⅱ. MIMO CamCom Architecture

In the MIMO VCO CamCom model, the optical transmit element generates an optical signal which is modulated by OOK modulation. The output power is proportional with the electrical input power. The MIMO concept is based on multiple transmit elements of a light emitting array and cell demodulation in camera received image. Every cell will modulate for one bit stream. The pixels in a camera can essentially be viewed as an array of highly directional received elements. The system model is shown in Figure 1.

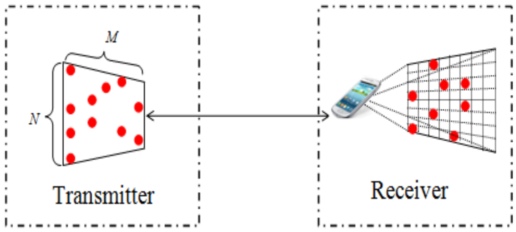

Fig. 1. MIMO VCO CamCom model

The optical transmitter includes array of M x N transmitting LED as elements communication. The data stream will be converted from serial to parallel for modulation process in LEDs. Every LED will modulate the digital data bit using OOK modulation. The transmission operation will be formatted as Figure 2. There will be 2 of 30 camera frame rate for the synchronization period. The pattern frame for synchronization is formatted as Figure 3.

The optical signal from the transmit element (N x M) emitting a light beam will be transmitted into the channel. At the receiver, the camera will capture the image of transmitter pattern and demodulate the embedded data in group of pixels as cell of MIMO transmission.

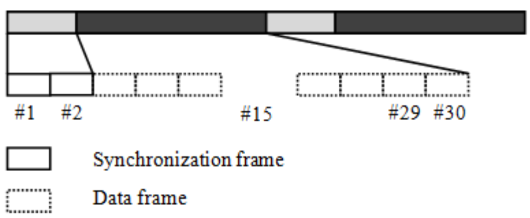

Fig. 2. Transmission frame format

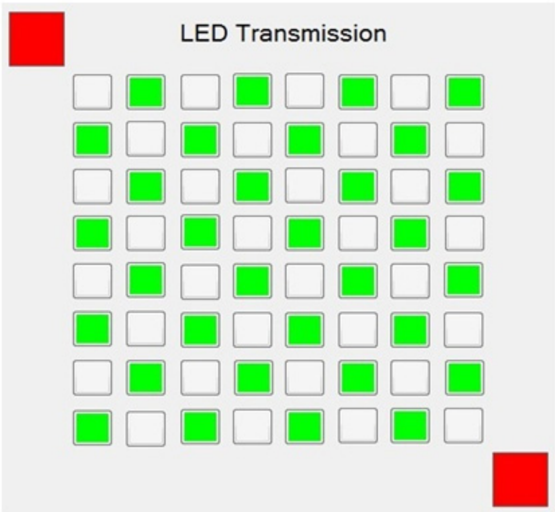

Fig. 3. Synchronization pattern

The data frame from parallel data bits are modulated on LED array. Figure 4 shows an example of the modulated process. Every bit in 8 group bits will be represented by one LED with two states (ON-OFF).

For a static transmitter and receiver, the image of the LED array transmit elements captured by the camera spans one pixel or multiple pixels. Further, the image plane is spanned by images of each transmit element clearly delineated and the size of image span depending on the focus of the camera. The sampling for receiving image must be synchronized as Figure 5. We will analysis this problem in next section.

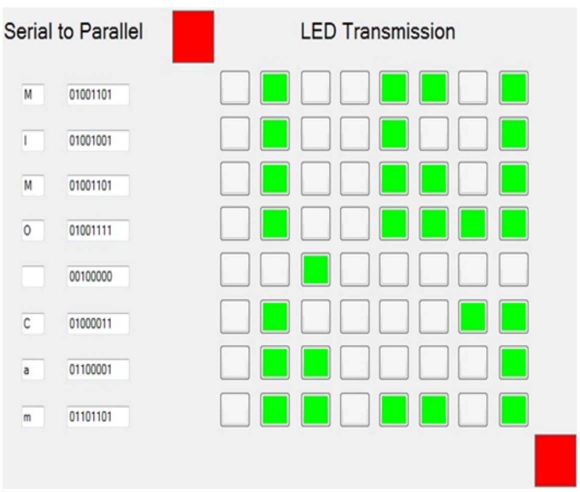

Fig. 4. Data frame modulation

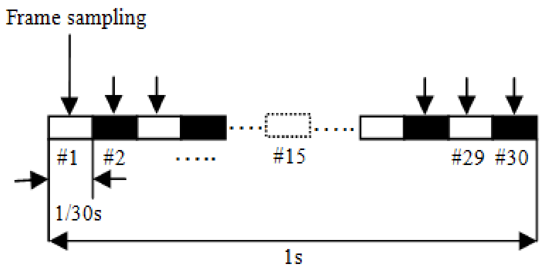

Fig. 5. Frame sampling

The receiving operation is shown in Figure 6. One of the most important in receiving side is frame synchronization from camera. Decoding the receiving image, receiving will try to sampling and get it in two frames with the rate 30 frames per second. If in the first frame, it cannot synchronize, the camera will set the delay a half frame rate to synchronize the second frame.

The receiving transmitter pattern will decode the transmission data by comparison the ratio of the setting color pixels with background. If the ratio of setting color in that cell is larger than threshold, it will decode the 1 bit. Figure 7 shows the example scenario of decoded data of pattern.

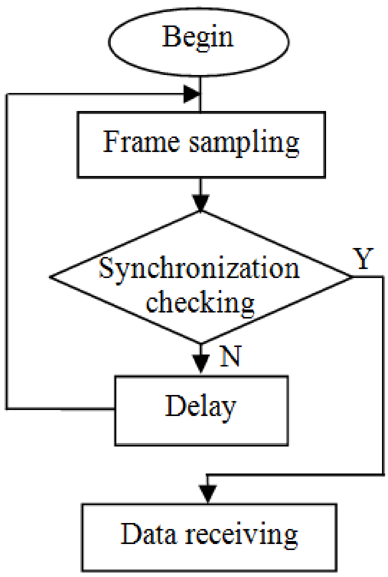

Fig. 6. MIMO operation

Ⅲ. Performance Analysis

3.1. Synchronization

Assume that the frame rate of receiving camera is

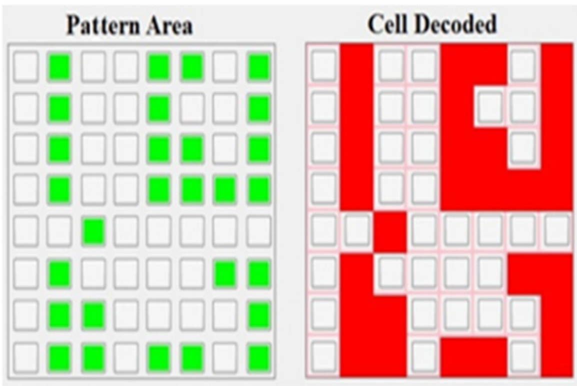

Fig. 7. MIMO data decoding

30 fps. The frame sampling of receiving camera for Assume that the frame rate of receiving camera is 30 fps. The frame sampling of receiving camera for successful synchronization is represented in Figure 7. In this scenario the sampling period will be in one modulated frame duration. The synchronization can be unsuccessful if the frame sampling is the Figure 8. In this scenario, the two sampling will occur in one frame. That mean the receiving images of two sampling period will be same.

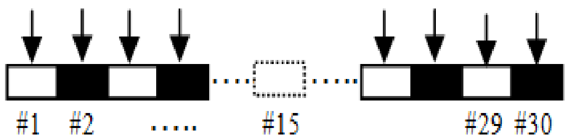

Figure 7. Sampling in successful synchronization

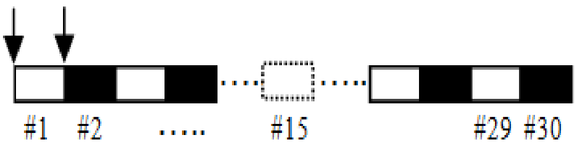

Fig. 8. Sampling in loss synchronization

3.2. Implement Experiment

We implement the proposed architecture based on Visual Studio C# and Computer Vision for LED transmission controlling and MIMO decoding. The operation of transmitter and receiver are shown Figure 9 and Figure 10. At the transmitter side, the serial binary bits data are grouped in eight bits group and converted in to parallel stream. The bit stream will control the vertical LED array. The optical channel is presented as LED array status. At the receiver side, camera will sample image frame at 30fps. The sampling period must be synchronized as synchronization scheme which discuss in previous section. The receiver will detect the transmitter pattern by using pattern recognition of computer vision function. After extracting the transmitter pattern, the application continues classify the cells partition and detecting status of cell of LED transmitter. Most important process in receiver is pattern recognition, we embedded Aforge computer vision library for transmitter pattern extraction. The distance range for communication can be control by zoom lens ability of camera.

The experiment was applied for text transmission. The input text will be grouped by 8 character block. Every character will decoded an ASCII binary code and converted into parallel transmission by vertical LED array. The receiver will decode the transmission bit from cells pattern and reconvert in to ASCII character.

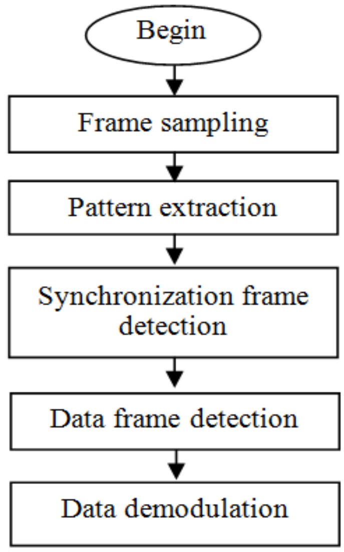

Fig. 9. Receiver operation

Figure 11 and Figure 12 show the performance with another configuration of LED array. The data rate is strongly effect by the rate of LED array. It can be a trend direction for Mbps. However, with the effect of the blur the circumference of the two transmit element images are separated by one pixel they may not be resolvable. The threshold distance of separation between the images of the transmit elements should be considered for system designing.

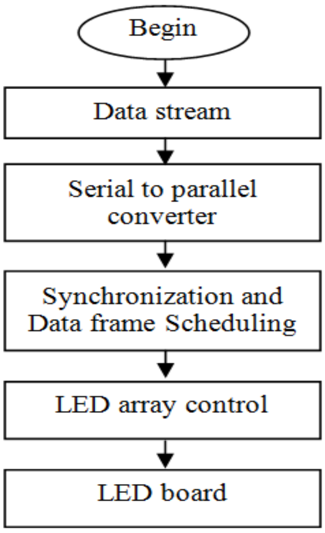

Fig. 10. Transmitter operation.

The characteristic of system is in Table 1. And the results measurement of experiment is shown in Figure 13. The most important issue in our proposed system is the cell classification. When the distance between the transmitter and receiver is increased the blur effect will be more strongly. This makes the receiver can not separate the cells in the pattern image.

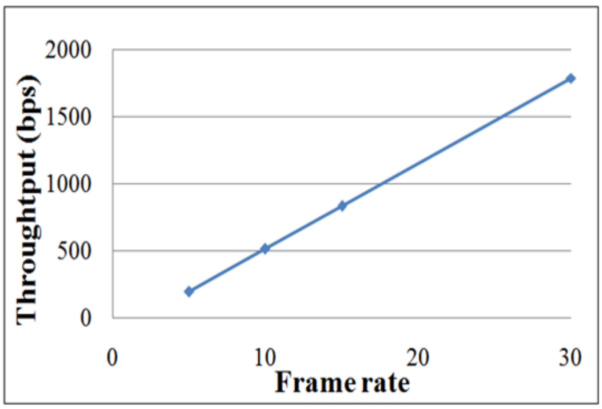

Fig. 11. Throughput performance

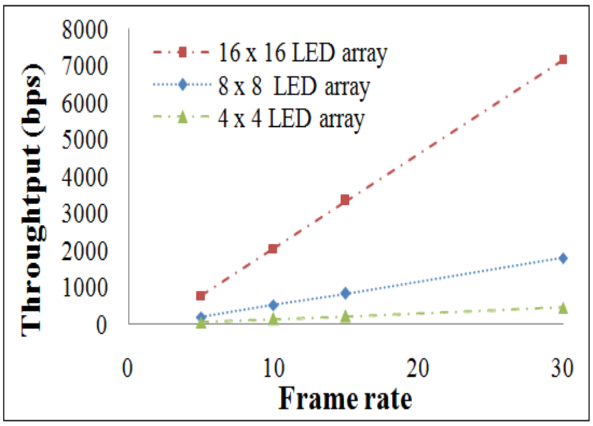

Fig. 12. Performance of VCO

Table 1. System information

Characteristic	Information
Camera	SPC-A400MB
Resolution	640 x 480
Max Frame rate	30
LEDs distance separation	3 mm
LED cell	7 x 7 mm^2
LED array	8 x 8

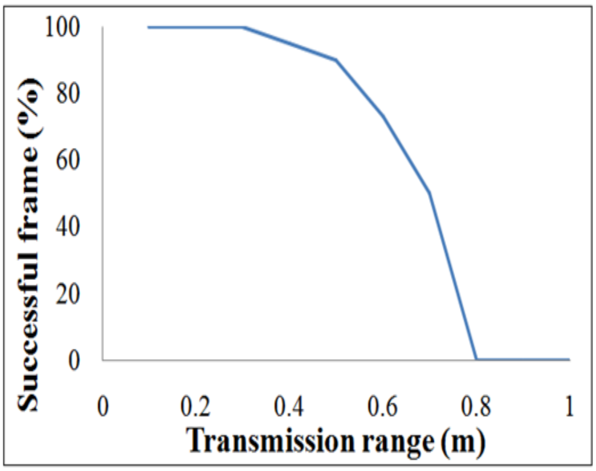

Fig. 13. Blur effect

Ⅳ. Conclusion

In the concept multiple transmit elements of a light emitting array are used as transmitters to communicate to the individual pixel elements of the camera which act as multiple receive elements to create the visual MIMO channel. The received signal is essentially the image of the multi LED transmitting element. Using recognition computer vision and OOK modulation, the proposed system, visual Cell OOK modulation, which based on the MIMO technology, is a promising future trend of Visible Light Communication.

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