논문 16-41-02-07 The Journal of Korean Institute of Communications and Information Sciences '16-02 Vol.41 No.02
http://dx.doi.org/10.7840/kics.2016.41.2.198

Invisible 워터마킹 기반의 광무선통신

Invisible Watermarking Based Optical Wireless Communications

Mohammad Arif Hossain◆, Nam-Tuan Le*, Amirul Islam*,
Chang Hyun Hong*, Yeong Min Jang°

ABSTRACT

In the contemporary world, the breakthrough of the ultra-modern technologies has been blessed with the camera. This device has become omnipresent either integrated on with other devices such as smartphones, notebooks, laptops, handheld devices and so on. In addition, digital signage, display and monitors have also become very widespread around us everywhere. These types of scenarios have made imaginable to imagine about the consuming of the unused resources. The dual use of displayed contents can make it possible to use it as an advertisement as well as a transmitter for camera based communication. In this study, a digital watermarking algorithm based communication method has been analyzed. We have introduced Binary Pattern (BP) based a new message extracting algorithm to extract message in an efficient way from the watermarked image compared to other algorithms. Besides, the previous works using camera and display have been illustrated using comparative analysis. This paper has demonstrated an advantageous overview using the experimental results which reveals that the proposed methodology significantly reduces the complexity while augmenting the advantages of the proposed scheme. Moreover, the simulation results have shown the advantages of the proposed scheme over the other schemes.

Key Words : Digital watermarking, invisible image sensor communication, binary pattern, SSIM, PSNR.

Ⅰ. Introduction

The recent world is going through a revolutionary change in the technologies. The use of the camera in different devices has made the world more flourished to create an innovative structure for wireless communications. It is very auspicious for the users to have a mounted camera device in most of the devices they are using in their everyday life. In addition, the display of the advertisement or digital signage has created an opportunity to establish a communication between display and camera[1]. This communication has opened several applicable field that can be helpful to accelerate the advertisement procedure. This technique is pointed out a usage of unused resources in a quite technical way. The most appealing phenomenon of this type of communication is that the dual use of the display for both advertisement and communication is quite possible simultaneously.

Digital watermarking is one of the good candidates to introduce the simultaneous communication between digital signage and camera even though there are some other methods. The

※ This work was supported by Institute for Information &communications Technology Promotion (IITP) grant funded by the Korea Government (MSIP) (No. R0127-15-1025, Development of Optical Wireless Communications (OWC) Standardization).
◆ First Author : Kookmin University, School of Electronics Engineering, dihan.kuet@gmail.com, 학생회원
° Corresponding Author :Kookmin University, School of Electronics Engineering, yjang@kookmin.ac.kr, 종신회원
* Kookmin University School of Electronics Engineering, 학생회원
논문번호 : KICS2015-12-411, Received December 28, 2015; Revised February 5, 2016; Accepted February 15, 2016

hiding of a message related to a digital signal such as an image, video etc. inside the signal is called digital watermarking. Although this is a very close concept related to the steganography process, but the objective of the procedures are different because the digital image is just work as a shield in the steganography process while the digital image is part of the message in digital watermarking[2,3]. The applicability of digital watermarking has made it possible for the communication purposes. The main challenge of this procedure in communication is the act of making the watermarked portion invisible to the human eye as it is performed for dual functionality in digital signage (i.e. advertisement and communication). Nevertheless, there are several methods that have been discussed in some research work with some limitations.

However, the applicable field for camera based communication is not limited to digital signage application rather than there are numerous applications. The innovative advertising applications, for instance, video clips, URL link of the websites, LCD display, electronic billboard, digital maps and so on. This types of application can be very useful to use in navigation purposes such as wayfinding for unknown exploration in the museum, hill, mountain etc. It is quite feasible to use this technology in the application of vehicle to vehicle communication, ship to ship communication, robot to robot communication and so on. Besides, supermarket advertisement for sales and the advertisement for selling and buying from remote places is possible using this type of communication technology.

This paper is an illustration of a communication scheme using digital watermarking, especially for image sensor communication (ISC) which includes the camera-based application. Our proposed scheme is based on color modulation to eliminate the geometric and photometric distortion in the display image. The rest of this paper is systematized as follows. In Section II, the related works with some analysis have been explained. Section III represents the proposed methodology while the mathematical modelling and experimental results have been given in section IV and section V, respectively. The paper concludes in Section VI.

Ⅱ. Related Works

There are several ways demonstrated in the previous works to establish a successful communication even though there are various types of difficulties in those techniques. Visual MIMO (multiple input multiple output) is one of the described procedures that are adopted with a view to laying a foundation for Invisible communication. Steganography technique is followed to hide data inside of an image in order to communicate with a camera[4]. This method is mainly based on computer vision techniques to remove the geometric effect created by a camera. Nevertheless, there is no clear explanation on the effect of illumination of environmental lighting and other sources of light. In addition, the data extraction procedure is ambiguous in this method. Another technique based on message embedding procedure has been demonstrated for a successful dynamic and invisible communication [5] which also contains the computer vision technique to solve the geometric issues. The results of the proposed method show that there is an absolute degradation in the accuracy of the data received while the effect of distance is explained in the research work. The distance has a great impact on both of the data rate and bit error rate.

A communication between a LCD display and a camera has been proposed in which the message is considered as time-varying while the position of the camera is kept as unchangeable[6]. Similar research like camera based communication has been conducted in [7] which is a demonstration on barcode modulation method in order to transmit data in mobile devices containing a camera. This method has demonstrated the technique to transmit a barcode image on a cell phone from another cell phone and to decode the data through the camera of the second cell phone. Nevertheless, this technique has used display to camera communication with a stability against the camera movement, illumination, blurred image, and the light leakage etc. but this is only useful only for 2D barcodes as the barcode sequence is used the modulation technique which has limited the applicable field to be used in most of the service scenarios. We have proposed a digital watermarking based ISC technique which is capable of eliminating the problem of both geometric and photometric complications related to distortion, distance, illumination and so on. We have demonstrated Binary Pattern (BP) algorithm to extract the information from the digitally watermarked image. The BP algorithm is totally capable of interpreting the message inside an image while the illumination is not a matter of concern. This is a fast extracting method compared to other message extracting algorithms. Hence, the computer vision algorithms to reduce the geometric and photometric illumination are not included in our technique which reduces the complexity of the process.

Ⅲ. Planned Methodology

The novelty of our proposed scheme is the use of binary pattern (BP) matching algorithm to extract the embedded in the digitally watermarked image. The matching algorithm makes the proposed method more universal to cope with other method and more feasible. It enhances the efficiency in the computing algorithm. Hence, the efficiency of the proposed algorithm is very high. However, this scheme is highly suitable for extracting embedded message in an image while the image is compared to the same type of image which does not include the embedded messages. Moreover, this algorithm has no effect in a uniform changing of the illumination in the environment. The use of binary pattern makes it simpler to make a comparison with the change in intensity in image pixel without considering the illumination. The message embedding and extracting algorithms have explained with the mathematical demonstration in this section.

Generally, a common image sensor device has a rate of 30 frames per second (fps). Thus, we can get 15 images without any embedded message which can be called reference images and 15 images with messages in the camera of 30 fps. But this type of communication has low data rate because the watermarking can cause distortion to image which will be very disgusting to the user. The image quality and data rate have a tradeoff in this case. Nevertheless, the computational complexity has also a great impact on the data rate as the complexity in computation can delay the data analysis after reception of transmitted image. However, some of the camera devices have the frame rate over 30 fps such as 60, 100 and even thousands of fps. Consequently, a high data rate can achievable in that kind of devices. Keeping the computational complexity and lower data rate in mind we have proposed that the reference and the watermarked image have been resized in a small part (m x m pixel) to reduce the computational complexity for comparison of the image.

The next step begins with the embedding of message in image which is one kind of change of intensity in the image. The making of change in the intensity is very crucial step as the change can make distortion visible to human eye. Thus, a negligible amount of intensity has been changed which can be visible to camera. The image is embedded with message similar to the addition of checkerboard image to an image where the number of rows and column of the checkerboard depends on the number of bit which have to be embedded which is shown in Fig. 1. For example, if 4 bit message data is proposed to extract from the watermarked image, the image is watermarked in such a way that the image looks very similar to a 2x2 checkerboard image where the change of intensity in the watermarked image is very negligible. The data rate is related to the checkerboard as the image pixels are changed

(a) Original Image (b) Watemarked Image

Fig. 1. Image of original and watermarked image.

according to the black and white part of the checkerboard. The white part of the checkerboard means that there is no change in the intensity of the pixels of that part of an image while the black part indicates the change in intensity. However, the checkerboard can be of any size. The algorithm shown in Fig. 2 represents the data embedding procedure.

The topology of the recovery of embedded message is related to the comparison of pixel value of the reference and watermarked image after resizing the image to reduce the computational complexity. The intensity of the pixel of both resized image is checked by creating a window. However, we have used 3x3 window to check the pixel intensity. The pixel of the window image is denoted by $(I_{i1,j1})$, $(I_{i2,j2})$, $(I_{i3,j3})$ and so on which is shown in the Fig. 3. However, any pixel with same intensity in the reference and watermarked image can be chosen as a centre point to compare. One example has been illustrated in the Fig. 4(a) and Fig. 4(b), where the intensity of the pixels in the window of reference image and watermarked has been shown, respectively. The comparison between a pixel of reference image and watermarked image has been depicted in the figure. The changing pixel value has given color. Comparing the intensity of the pixels in the reference image and in the watermarked image we can get the binary value. The change in intensity in any pixel either

$I_{i1,j1}$	$I_{i2,j2}$	$I_{i3,j3}$
$I_{i4,j4}$	$I_{i5,j5}$	$I_{i6,j6}$
$I_{i7,j7}$	$I_{i8,j8}$	$I_{i9,j9}$

Fig. 3. Intensity comparison method to extract the embedded message from watermarked image

increasing or decreasing is denoted by 1 according to (1) and the unchanged pixel is denoted by 0. B is the function of binary value where $k(i, j)$ is the difference between the intensity of pixel $I(i, j)$ in the resized reference image and the resized watermarked image and the intensity is denoted by $(I_{i,j})_R$ and $(I_{i,j})_W$ for the reference image and the watermarked image, respectively.

$$B(k(i,j)) = 1; k(i,j) > 0 \,\text{or}, k(i,j) < 0 \qquad (1)$$

where, $k(i,j) = (I_{i,j})_R - (I_{i,j})_W$.

The binary values of a window has shown in the Fig. 4(c) where the two column is 0 and the other column is 1. When the window is checking the pixel values, the binary values of the window will be all 1 or all 0 or some 1 and some 0 because the black checker board pattern makes changes in intensity while the white one does not. According to our proposed scheme, if all of the binary value of the window is 1, then it will be taken as 1 for the

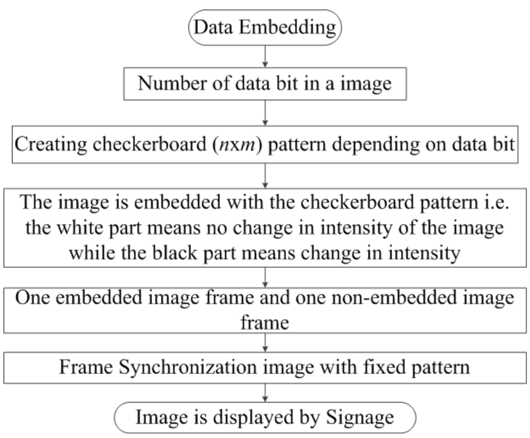


Fig. 2. Algorithm for data embedding procedure.

70	60	40
45	50	30
35	55	45

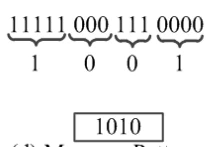
(a) Reference Image

70	60	55
45	50	45
35	55	60

(b)Watermarked Image

0	0	1
0	0	1
0	0	1

(c) Binary Pattern of a window



(d) Message Pattern

Fig. 4. Illustration of binary pattern and message bit extracting algorithm.

window operation. Otherwise, it will be considered as 0. Thus, a binary value will be achieved after the comparison of the pixel value by the window.

Let us assume that the obtained binary value of the resized image after the window operation is 111110001110000. However, the sequential 1 represents a '¡0' whereas the sequential 0 indicates a '0'. Thus, the received bit pattern becomes 1010. The procedure has been depicted in the Fig. 4(d). The data extracting algorithm for the receiver side has been elucidated in the Fig. 5.

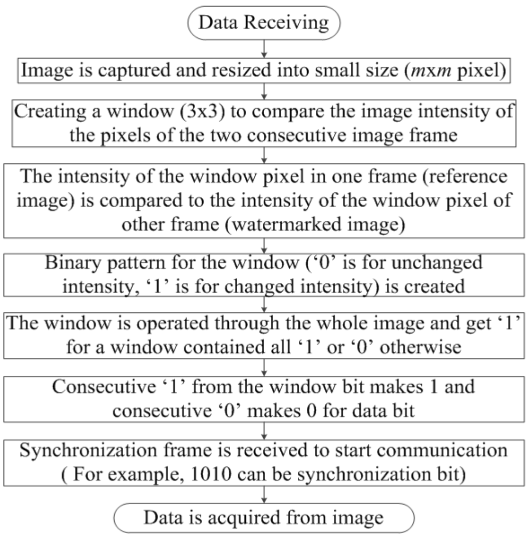


Fig. 5. Algorithm for data extracting method.

Ⅳ. Performance Evaluation

The performance of the watermarking based communication is mainly depend on the watermarking pattern. Nevertheless, the watermarking of an image should not distort the image quality. Otherwise, the main purpose of the image or video broadcasting in the digital signage, television or in any device will be failed. Thus, distortion measurement has become a key point in case of watermarking an image. Structural similarity is one of the vital issue to measure distortion in an image. It depends on the similarity of luminance, contrast and the structure of an image. The luminance similarity of the reference image and the watermarked image are estimated by comparing the mean intensity of the image pixel whereas the contrast similarity and structure similarity are assessed by matching the standard deviation (square root of variance) and normalized standard deviation of the images, respectively. The luminance similarity, contrast similarity and structure similarity can be expressed by (2), (3) and (4), respectively.

$$L(i,j) = \frac{2\mu_R(i,j)\mu_W(i,j) + B_1}{\mu_R^2(i,j) + \mu_W^2(i,j) + B_1} \quad (2)$$

$$C(i,j) = \frac{2\sigma_R(i,j)\sigma_W(i,j) + B_2}{\sigma_R^2(i,j) + \sigma_W^2(i,j) + B_2} \quad (3)$$

$$S(i,j) = \frac{\sigma_{RW}(i,j) + B_3}{\sigma_R(i,j) + \sigma_W(i,j) + B_3} \quad (4)$$

where μ_R, μ_W, and σ_R, σ_W denotes the mean intensity and standard deviation of the reference image and the watermarked image, respectively. B_1, B_2, and B_3 represent the constants which are empirical value. The mean intensity and the variance of an image signal M can be expressed as (7) and (8), respectively while the variance between two image signal P and Q can be stated by (9) which is used to measure the structural similarity between the image signals. An analytical procedure for estimating structural similarity (SSIM) between the images has been illustrated in Fig. 6[8].

$$\mu_M(i,j) = \sum_{x=-X}^{X}\sum_{y=-Y}^{Y} g(x,y)M(i+x,j+y) \quad (5)$$

$$\sigma_M^2(i,j) = \sum_{x=-X}^{X}\sum_{y=-Y}^{Y} G(x,y)[M(i+x,j+y) - \mu_M(i,j)]^2 \quad (6)$$

$$\sigma_{MN}(i,j) = \sum_{x=-X}^{X}\sum_{y=-Y}^{Y} G(x,y)[M(i+x,j+y) - \mu_M(i,j)] \times [N(i+x,j+y) - \mu_N(i,j)] \quad (7)$$

where G(x, y) represents the Gaussian weighting

$$\sum_{x=-X}^{X}\sum_{y=-Y}^{Y} G(x,y) = 1$$

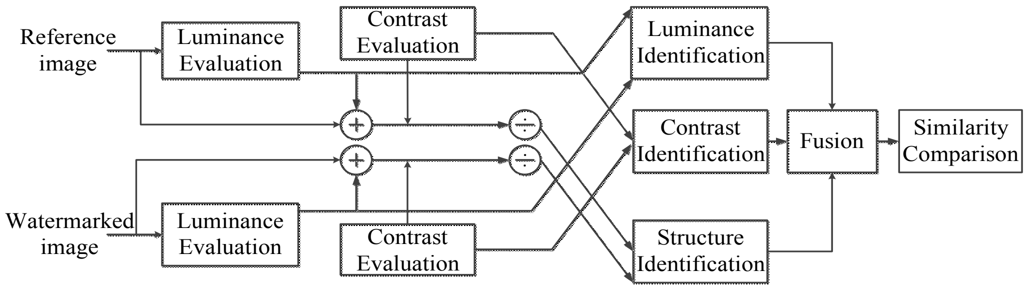


Fig. 6. Structural similarity analysis procedure.

function and. However, B_1, B_2, and B_3 can be expressed as

$$B_1=(F_1r)^2,\ B_2=(F_2r)^2 \text{and}\ B_3=F_2/2$$

Here, r is the range of the image and F_1 and F_2 are small constants and F_1<<1, F_2<<1.

The SSIM function can be calculated by combining (2), (3) and (4) which is the similarity function as shown in (8).The mean square error (MSE) between the two images has been estimated for evaluating the error rate of the images which can be expressed as

$$SSIM(i,j)=[L(i,j)].[C(i,j)].[S(i,j)] \tag{8}$$

$$MSE=\left[\frac{1}{R\times C}\right]^2\sum_{i=1}^{R}\sum_{j=i}^{C}(I_R(i,j)-I_W(i,j))^2 \tag{9}$$

where $I_R(i,j)$ and $I_W(i,j)$ represents the intensity of the pixel of the reference image and the watermarked image, respectively while R and C represents the row and column value of the images. The peak signal to noise ratio (PSNR) has a great impact on the quality of image which has also been assessed that interprets the difference of the quality of the reference image and the watermarked image. It can be denoted as

$$PSNR=20\log_{10}\left(\frac{255}{RMSE}\right) \tag{10}$$

where RMSE indicates the square root of MSE and 255 stands for the 8 bit used for colors of the pixels.

The data rate is same to the checkerboard pattern of watermarked image. We have embedded five different checkerboard patterns to assess simulation results with respect to data. We have considered a camera of 60 fps. The data frame will be half of the camera frame rate. We have embedded 4, 6, 8, 9, 12, and 16 bit in every image to get 120, 180, 240, 270, 360, and 480 bit per second (bps), respectively. However, the rate of change in SSIM value which is shown in percent value with respect to data rate is shown in Fig. 7. The SSIM value varies insignificantly even though the change in data rate is very high which implicates the suitability of the proposed scheme. The peak signal to noise ratio (PSNR) value of the watermarked image with the change of data rate is also changed with a little variation which is shown in Fig. 8.

The mean square error of the watermarked image is also estimated to find out the quality of the image with compared to the original one. The comparison of MSE value among the red, green and blue colors

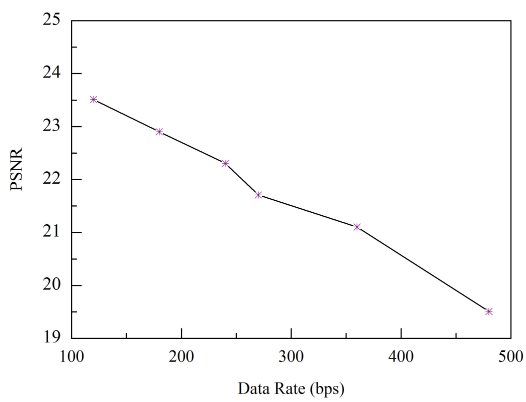


Fig. 7. Comparison of SSIM with respect to data rate.

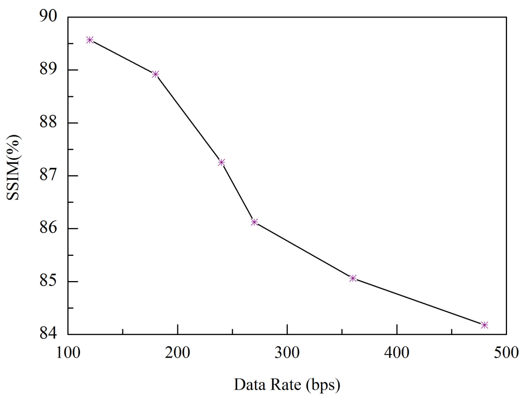


Fig. 8. Comparison of PSNR with respect to data rate.

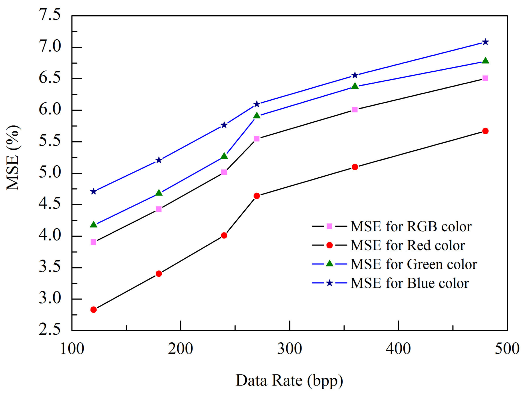


Fig. 9. Comparison of MSE with respect to data rate.

along with the combined color is shown in Fig. 9. The MSE value is shown in percent value. It is very obvious from the Fig. 9 that the red color has the least MSE value and the blue color has the most MSE value among the RGB colors. Human eye is less sensitive to the change in blue color. A little change in blue color can be invisible to human eye.

V. Conclusion

Digital watermarking has made a great opportunity to communicate via image in a simple and easy way. This opportunity has opened new applicable such as digital signage and camera communication, device to device communication and on. Our proposed scheme is a simple illustration of image based communication. This strategy has the advantage of alleviating the illumination effect. Moreover, it is simple and the computational complexity is very low. Nevertheless, the geometric problem can also be solved in many cases using this method. In addition, the use of image or video in communication can solve the traffic problem in the conventional cellular network. The main drawbacks of the technique is the low data rate. The future work will include the photometric and geometric solution of the real-time communication method. Artificial intelligence can be good candidate to solve the geometric and the photometric problem in the communication method.

References

[1] W. Yuan, K. J. Dana, A. Ashok, M. Gruteser, and N. Mandayam, "Spatially varying radiometric calibration for camera-display messaging," in *Proc. Global Conf. Signal and Inf. Process.*, pp. 763-766, Austin, TX, Dec. 2013.

[2] Q. Wang, W. Zeng, and J. Tian, "A compressive sensing based secure watermark detection and privacy preserving storage framework," *IEEE Trans. Image Process.*, vol. 23, no. 3, pp. 1317-1328, Mar. 2014.

[3] Y. Tew and K. S. Wong, "An overview of information hiding in H.264/AVC compressed video," *IEEE Trans. Cir. and Syst. for Video Technol.*, vol. 24, no. 2, pp. 305-319, Feb. 2014.

[4] W. Yuan, K. Dana, A. Ashok, M. Gruteser, and N. Mandayam, "Dynamic and invisible messaging for visual MIMO," in *Proc. IEEE WACV*, pp. 345-352, Jan. 2012.

[5] W. Yuan, K. Dana, M. Varga, A. Ashok, M. Gruteser, and N. Mandayam, "Computer vision methods for visual MIMO optical system," in Proc. IEEE CVPRW, pp. 37-43, Jun. 2011.

[6] S. D. Perli, N. Ahmed, and D. Katabi, "Pixnet: designing interference-free wireless links using LCD-camera pairs," in *Proc. 16th Annu. Int. Conf. Mob. Comput. Netw.*, pp. 137-148, Sept. 2010.

[7] A. Motahari and M. Adjouadi, "Barcode

modulation method for data transmission in mobile devices," *IEEE Trans. Multimedia*, vol. 17, no. 1, pp. 118-127, Jan. 2015.

[8] M. A. Hossain, Y. T. Lee, H. Lee, W. Lyu, C. H. Hong, T. Nguyen, N. T. Le, and Y. M. Jang, "A symbiotic digital signage system based on display to display communication," in *Proc. ICUFN*, pp. 124- 128, Jul. 2015.

Mohammad Arif Hossain

2014년 9월 : Khulna University of Engineering and Technology in Electrical and Electronic Engineering 졸업

2014년 9월~현재 : 국민대학교 전자공학과 석사과정

<관심분야> Image Processing, Computer Vision, Optical Wireless Communication (OWC), Digital Signage, Internet of Things (IoT)

Nam-Tuan Le

2005년 2월 : HaNoi University of Science and Technology 졸업

2011년 8월 : 국민대학교 전자공학과 석사

2014년 2월 : 국민대학교 전자공학과 박사과정

2014년 3월~현재 : 국민대학교 조교수

<관심분야> Sensor Network, Visible Light Communication

Amirul Islam

2014년 9월 : Khulna University of Engineering and Technology in Electrical and Electronic Engineering 졸업

2015년 9월~현재 : 국민대학교 전자공학과 석사과정

<관심분야> Localization, SDN, Optical and Camera Communications

Chang Hyun Hong

2015년 2월 : 국민대학교 전자공학부 졸업

2015년 3월~현재 : 국민대학교 전자공학과 석사과정

<관심분야> Optical Wireless Communication, Image processing

Yeong Min Jang

1985년 2월 : 경북대학교 전자공학부 학사

1997년 2월 : 경북대학교 전자공학부 석사

1999년 8월 : Univ. of Massachusetts Computer Science 박사

2002년 3월~현재 : 국민대학교 교수

<관심분야> OWC, WPAN, IoT, 5G Mobile communications