Deep learning technique for improving data reception in optical camera communication-based V2I

Dong Nyeok Choi, Sung Yooun Jin and Juhee Lee
Department of ICT Automotive Engineering
Hoseo University
Dangjin-si, Chungcheongnam-do, 31702, Rep. of Korea
{ dongnuik12, jinsungyooun92}@gmail.com, juheelee@hoseo.edu

Byung Wook Kim
Department of Information and Communication Engineering
Changwon National University
Changwon-si,Gyeongsangnam-do, 51140, Rep. of Korea
bwkim@changwon.ac.kr

***Abstract* - Recently, as the existing lighting infrastructures are replaced by LED lighting, optical camera communication (OCC) technology in vehicle-infrastructure communication (V2I) systems have been actively researched. In this paper, we introduce a method to improve data packet reception rate of OCC-based V2I by using deep learning based region-of-interest (ROI) detector. In the V2I environment, traffic lights on the roadside are ROIs that perform as transmitters sending OCC data, and should be detected at the receiving camera. If ROI detectors utilize a deep learning model, data can be extracted stably during actual driving. From the experiment result, it was found that data packet reception rate using deep-learning based ROI detection technique outperforms that of conventional method based on image differentiation.**

Index Terms – Optical camera communication, vehicle-infrastructure communication, deep learning model.

I. Introduction

Recently, lighting infrastructures on the road are changing to LED lighting. Since the fast switching functionality of LED can be utilized for data communication, researches on optical camera communication (OCC), which is an LED-IT convergence technology using LEDs and cameras as transmitting and receiving ends, respectively, are actively conducted [1-2]. Since LEDs and cameras are already widely used on roadsides and vehicles, it is easy to apply OCC to vehicle-infrastructure communication (V2I) to exchange traffic information. At the OCC receiver, traffic lights sending OCC data becomes region-of-interests (ROIs), and should be detected to decode the data bit sequence.

Recent advances and performance of deep neural networks have made significant improvements in several areas of image classification, object detection and other applications of computer vision [3-5]. Especially, research related to traffic light detection have benefited greatly from deep learning model. K. Behrendt et al. [6] proposed a system for detection, tracking, and 3D localization of traffic lights utilizing deep learning. Deep traffic light recognition (DeepTLR) for traffic light recognition based on a ConvNet has been addressed in [7]. In [8], two heuristic traffic light detection methods to a state-of-the-art learning-based detector relying on aggregated channel features were compared.

In this paper, we address a scheme for improving data reception in OCC-based V2I using deep learning approach. The detection of ROI is carried out by a trained neural network, and OCC data can be retrieved from consecutive image frames. Experimental results proved that the performance of data reception using deep neural net outperforms that of conventional method. The data packet reception rate improved approximately 8.2% and 14.7% when vehicle is running at 20 km and 50 km speed, respectively.

II. Traffic light detection in OCC-based V2I

A. OCC system for V2I

In the V2I environment, the LED light source of the traffic light transmits the road information data using the visible light modulation method. The intensity variation of the optical signal contains digital bit sequences and can be detected via camera sensors. From the captured image, the traffic light is displayed on the image pixels, and successive image frames are accumulated to retrieve the data packet.

To detect ROI in the conventional OCC method, the image difference using the On-Off pattern of the visible light modulation signal is used. However, the differential image becomes ambiguous when captured images are blurred due to the vehicle movement, and that eventually lowers the data packet reception rate. Although various image processing techniques such as color thresholding and template matching can be used to solve this problem, these techniques largely depend on the strong assumptions of image size and distinctive background [6], and thus, reliable performance cannot be guaranteed.

B. Deep learning-based ROI detection

As deep neural networks have recently proven to obtain robust results for visual object detection systems, they seem to be an appropriate method for realizing a robust ROI detection for OCC-based V2I. The learning process of the traffic light image was done through You only look once (YOLO), which supports high frames per second (FPS) and accuracy through fast preprocessing speed. Our deep learning model was composed of 22 Convolution Layer and 5 Max Pooling Layer by adding 3 more layers to the basic network structure of YOLO Version 3. For obtaining training data, 1600 images of 640x480 pixels obtained from the existing datasets for traffic light detection, and 1400 image data sets of 320x240 pixels obtained from the actual experiment were used. Since the position of the light source can be obtained in every image frame, the position of the light source is hardly lost in the middle, so the consecutive data can be stably received. Note that we can consider the YOLO bounding box as the ROI for extracting visible light data, because bounding boxes are fitted to pixel regions of traffic lights. Therefore, we analyzed the pixel distribution inside the box to distinguish the On-Off data bit. Since the OCC system needs to detect the data in successive frames, if the bounding box using YOLO is not generated, the bounding box in the previous frame was set to be used instead. The use of YOLO in OCC systems can be a viable solution for V2I applications due to its reliability, real-time process, and capability to obtain for both small and large objects.

III. Experiment Results

Fig. 1. Experimental environment for OCC-baed V2I

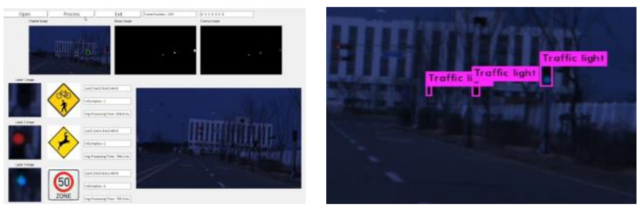

Fig. 2. GUI screen and traffic light detection using YOLO.

The experiment for OCC-based V2I was conducted on a real road as shown in Fig. 1, and the moving speed of the vehicle was set to 20 km/h and 50 km/h. Three traffic lights were used for visible light data transmission, and the distance between the traffic lights was set to 15m, and the height of the light source was 2.5m. The receiver used a 30fps Blackfly S camera and the transmitter used an embedded LED driver to transmit OCC data at an optical rate of 30Hz. The data packet is a total of 16 bits and consists of 8 bits of synchronization signal and 8 bits of road-side information. For the performance comparison, we obtained the data packet reception rate obtained by using ROI detection method based on image differentiation and YOLO, respectively. Fig. 2 shows the YOLO bounding box detection result and the GUI screen for analyzing the experiment results. Table 1 compares the data reception rate when using the conventional and deep neural network-based ROI detection techniques, respectively. As shown in Table 1, the deep learning-based method shows an approximately 8.2% and 14.7% increase in packet reception rate at 20 km and 50 km, respectively. The reception of data packets using the differential image approach may not be able to distinguish the complete ROI according to the moving state of the vehicle, which may result in a loss of the On-Off sequence in the middle. However, since YOLO utilizes weighted data in a deep neural network, ROI can be reliably obtained every frame, thus providing a high packet reception rate.

TABLE I. Performance comparison of data reception rate

Vehicle speed at 20km/h

	w/ conv. method			*w/ deep learning model*		
	LED1	***LED2***	***LED3***	***LED1***	***LED2***	***LED3***
No. of Tx packet	19.63	36.06	54.38	22.18	39.60	62.50
No. of Rx packet	15.00	26.00	37.00	18.00	29.00	50.00
Reception rate	76.41%	72.10%	68.04%	81.15%	73.23%	80.00%

Vehicle speed at 50km/h

	w/ conv. method			*w/ deep learning model*		
	LED1	***LED2***	***LED3***	***LED1***	***LED2***	***LED3***
No. of Tx packet	12.13	14.28	11.69	14.43	16.62	15.25
No. of Rx packet	9.00	10.00	7.00	12.00	12.00	12.00
Reception rate	74.20%	70.03%	59.88%	83.16%	72.20%	78.69%

IV. Conclusion

In this paper, we addressed a deep learning-based approach for improving data packet reception of OCC-based V2I. In order to reliably receive consecutive OCC data sent from traffic lights on the roadside, traffic lights should be recognized as ROIs at each frame and continuously detected. For this purpose, we adapt the YOLO deep learning model for the ROI detection in the receiving process. Experimental results proved that the ROI detection method using the deep neural network achieves a higher data reception rate than the conventional method based on the ROI from differential images.

Acknowledgment

This work was supported by Industrial Human Resources and Skill Development Program (N0001415, Display Expert Training Project for Advanced Display equipment and components engineer) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea).

References

[1] S. H. Lee, S.-Y. Jung, and J. K. Kwon, “Modulation and coding for dimmable visible light communication,” IEEE Communications Magazine, vol. 53, no. 2, pp. 136–143, Feb. 2015.
[2] N. T. Le, M. A. Hossain, and Y. M. Jang, “A survey of design and implementation for optical camera communication,” Signal Processing: Image Communication, vol. 53, pp. 95-109, Apr. 2017.
[3] J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, “You Only Look Once: Unified, Real-Time Object Detection,” in 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2016.
[4] O. Russakovsky et al., “ImageNet Large Scale Visual Recognition Challenge,” International Journal of Computer Vision, vol. 115, no. 3, pp. 211–252, Apr. 2015.
[5] J. Long, E. Shelhamer, and T. Darrell, “Fully convolutional networks for semantic segmentation,” in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, Boston, MA, pp. 3431–3440, Jun. 2015.
[6] K. Behrendt, L. Novak, and R. Botros, “A deep learning approach to traffic lights: Detection, tracking, and classification,” in 2017 IEEE International Conference on Robotics and Automation (ICRA), Singapore, Jun. 2017.
[7] M. P. Philipsen, M. B. Jensen, A. Møgelmose, T. B. Moeslund, M. M. Trivedi, “Traffic Light Detection: A Learning Algorithm and Evaluations on Challenging Dataset,” IEEE International Conference on Intelligent Transportation Systems, Las Palmas, Spain, Sept. 2015.
[8] M. Weber, P. Wolf and J. M. Zollner, “DeepTLR: A single Deep Convolutional Network for Detection and Classification of Traffic Lights,” 2016 IEEE Intelligent Vehicles Symposium (IV), Gothenburg, Sweden, Jun. 2016.