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IoT Open-Source and AI based Automatic Door Lock Access Control Solution

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Abstract

Recently, there was an increasing demand for an integrated access control system which is capable of user recognition, door control, and facility operations control for smart buildings automation. The market available door lock access control solutions need to be improved from the current level security of door locks operations where security is compromised when a password or digital keys are exposed to the strangers. At present, the access control system solution providers focusing on developing an automatic access control system using (RF) based technologies like bluetooth, WiFi, etc. All the existing automatic door access control technologies required an additional hardware interface and always vulnerable security threads. This paper proposes the user identification and authentication solution for automatic door lock control operations using camera based visible light communication (VLC) technology. This proposed approach use the cameras installed in building facility, user smart devices and IoT open source controller based LED light sensors installed in buildings infrastructure. The building facility installed IoT LED light sensors transmit the authorized user and facility information color grid code and the smart device camera decode the user informations and verify with stored user information then indicate the authentication status to the user and send authentication acknowledgement to facility door lock integrated camera to control the door lock operations. The camera based VLC receiver uses the artificial intelligence (AI) methods to decode VLC data to improve the VLC performance. This paper implements the testbed model using IoT open-source based LED light sensor with CCTV camera and user smartphone devices. The experiment results are verified with custom made convolutional neural network (CNN) based AI techniques for VLC deciding method on smart devices and PC based CCTV monitoring solutions. The archived experiment results confirm that proposed door access control solution is effective and robust for automatic door access control.

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1. Introduction

Nowadays, the safety and security are most challenges issues in modern time society to prevent people life and their valuables assets from illegal handling. As a result, the safety and security extending to personal social security to protect every individuals personal information, valuable things, and their day to day activities. Hence, the personal security services moving towards to integration of video surveillance, door lock access control system based on authorization information to avoid the access conflicts in personalized monitored areas [1, 2]. The personal authorization solution can be operated in the form personal computer (PC) based authorization or network based remote authorization or smart devices based local authorization, or printed documents based authorization and so on to minimize the illegal access risk in the building facility.

In recent days, the network based centralized electronic access control system developed for security gate control and door access control in smart buildings with different user authorization interfaces like near-field communication (NFC), radio-frequency identification (RFID), fingerprint recognizer, and face recognizer, etc. [3-7] to limit the physical access of the people in the buildings or assets. The building facility localized electronic access control system receives the user specific authentication and authorization information from a centralized access control system server and performs the automatic gate or door lock open or close control for the specific individuals to access building facility area using NFC or RFID Tag or fingerprint features or facial features, etc. The most available access control system user authentication interfaces are subject to the security compromising by exposing the password or digital keys to strangers. Also, the RF-based available user interfaces are vulnerable to security threats. However, the cost of the access control system installation is high, and the network interface has the weakness with access distance, security and network access efficiency issue.

The rapid development in smart devices and visible light communication (VLC) technologies set forth the new automatic door lock access control solution design and development. The advent of smart devices processing power and mega pixel feature support enable the optical camera communication (OCC) features can able to provide the personalized wireless data security and access control mechanism with high secured user access control. So this paper proposes a novel user identification and authentication solution for automatic door lock control operations using camera based visible light communication (VLC) technology. The proposed solution uses the IoT open-source light controller in the building facility to create lighting infrastructure and the artificial intelligence (AI) technology proposed for OCC receiver design. This paper describes the design of IoT open-source controller based lighting control to transmit the color grid code for VLC and AI based OCC receiver design for secure automatic door lock access control solution with the user smart device and infrastructure door lock installed to camera system.

The door lock access control system conceptual model and advancements are discussed in section 2. In the section 3 and 4, this paper describes the VLC for automatic door lock access control solution and proposed system architecture. The following section 5 presents the experimental results and analysis of the proposed automatic door lock access control solutions. Finally, the Conclusions are drawn based on the analysis in the section 6.

2. Door Lock Access Control System

The access control systems (ACS) designed to provide safe and secure access in the building facilities for

authorized individuals like homes, offices, factories, facility server rooms, airports, defense zone, banks. This system does not allow the unauthorized people to enter into the particular in the building facility. To secure a building facility, home or organizations use electronic ACS attached with door lock system that provide the access depends on the credentials given to the individual user, the access controller verify the data from ACS central server and then give the authentication to access the building facility locations and proprietary areas. The electronic door locks, are connected with access controller module, magnetic door locks interface, and door status sensors with uninterrupted power with batter power backups. The standard door access control system usage model is illustrated in the Figure 1.

The access controller module interface with the keypad or card reader, or finger print reader, or face recognizer to accept the individual users credential system. The access controller can work as a standalone or connected with ACS central server with Transmission Control Protocol/Internet Protocol (TCP/IP) to verify the individual users credential information for authentication. This restricts the strangers or unauthorized individuals to entry into the building facility, emergency alarms and facility lockdown capabilities and that prevent the unauthorized access and operations.

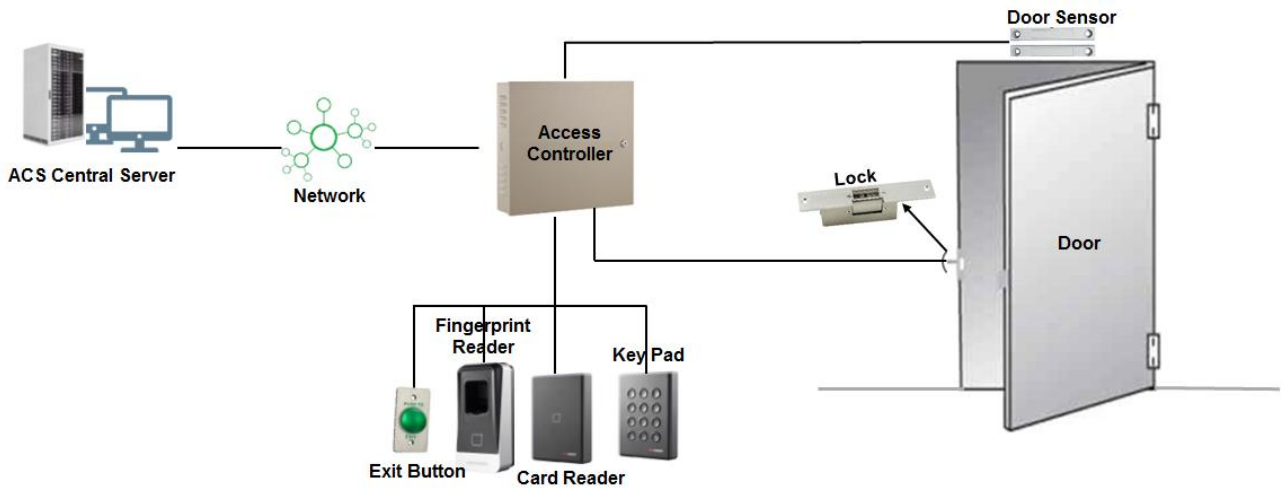


Figure 1. Door Access Control System

The door access control systems standardized based on the size of the building facility and the required varying levels of security on user access permissions given by the facility owner or administrator. As illustrated in Figure 1, the door access control systems are typically managed from the central location servers. Recently, some of the door access control system supported the radio frequency (RF) interface like NFC, RFID, bluetooth, Wi-Fi, etc. to support automatic door access through smart devices instead of standard credential feeder interfaces [8].

The most available access control system interface subject to the security compromising by exposing the password or digital keys to the strangers and RF interfaces are vulnerable to security threads. To avoid security compromises in the door access control system, this paper propose the VLC based door access control system design and the following section describes the concept structure and advantage of using VLC to design door access control solutions.

3. VLC for Automatic Door Lock Access Control Solution

The growing demands in the wireless connectivity push the RF wireless spectrum into the saturation end and need an alternative medium with huge spectrum bandwidth. Also, RF technologies are additive to the interferences and security threads. This paper considered the RF wireless connectivity limitations and issues into account to propose the VLC for door lock access control solution. The VLC have been considered for many wireless application services due to the security, wide spectrum availability, very low latency, and low power consumption [9, 10].

The VLC transmitters designed with light illumination device and receivers are designed using photo detection device likes photo diode (PD), camera sensor or image sensor, solar panels. The PD and solar cells works with same principle on receiving optical signal from light illumination devices but the camera or image sensor working with imaging system concept to decode the optically modulated light signal is called optical camera communication (OCC). In this proposed design, the smart device built-in camera based VLC solution considered to develop door access control system since the PD based VLC system required an additional receiver hardware module to interface with door lock control system as same as used in the RF based technologies. This camera based VLC approach uses the smart device cameras and door lock built in camera to develop VLC optical receivers without any additional HW components. The building facility installed IoT open source based lighting interface and the smart device LED interface to enable bi-directional VLC for highly secured door access control support. The camera based VLC system model is illustrated in Figure 2.

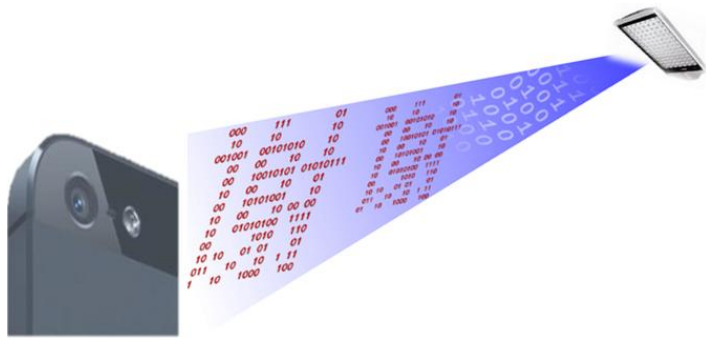


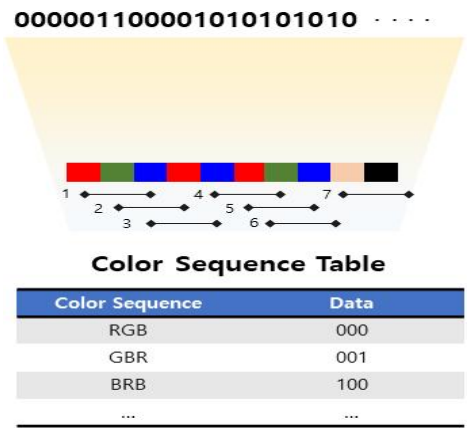
Figure 2. Camera based VLC System

The VLC has been standardized for PD, and OCC based optical wireless communication with various types of modulation schemes like On-Off Keying (OOK), Color-Shift Keying (CSK), variable pulse position modulation (VPPM), offset variable pulse width modulation (Offset-VPWM), variable transparent amplitude shape color (VTASC), and so on [9, 10, 11, 12]. In this proposed door access control solution, developed the new modulation scheme called color grid CSK which is four color palette sources blue, cyan, yellow and red (BCYR) colors. The BCYR color palette forms a quadrilateral constellation shape instead of triangular used in IEEE802.15.7 standards [9, 10] and this allows symbol mapping and constellation design as used in Quadrature amplitude modulation (QAM) schemes. The convolutional neural network (CNN) based AI techniques used in OCC receiver to recognize the color grid coded data. The CNN techniques improve the object detection efficiency in real-time [13, 14] and improve the VLC decoding latency. The following session discusses the detailed design architecture of the proposed system and system implementation details.

4. Proposed Door Lock Access Control System Architecture

The proposed solution utilizes the building facility lighting infrastructure, door lock built-in cameras, and

smart devices build-in camera, display, and LED to design VLC system for ACS. In this proposed approach, as discussed before "Color Grid" modulation scheme used for visible light communication that undergoes user authentication process using a smartphone's camera with LED transmitting color coded pattern. The color grid modulated coding sequence model is shown in Figure 3.



Color Sequence Table

Color Sequence	Data
RGB	000
GBR	001
BRB	100
...	...

Figure 3. Color Grid Modulation Coding Sequence

The grid color coded pattern generated using IoT open-source controller connected on lighting devices in the building facility. The smart devices recognize the LED transmitted grid color coded pattern through the camera and recognize the user stored authentication code and sends a response signal to the door lock connected camera for door control operation. The door lock connected camera recognize the color grid coded patter from smart device display or backside LED and make door open or close operation according to the acknowledgement received from the visible light spectrum. This method of performing communication maintaining physical security without compensating with network threads, which is an advantage of communication. The proposed VLC based automatic door lock access control solution illustrated in Figure 4.

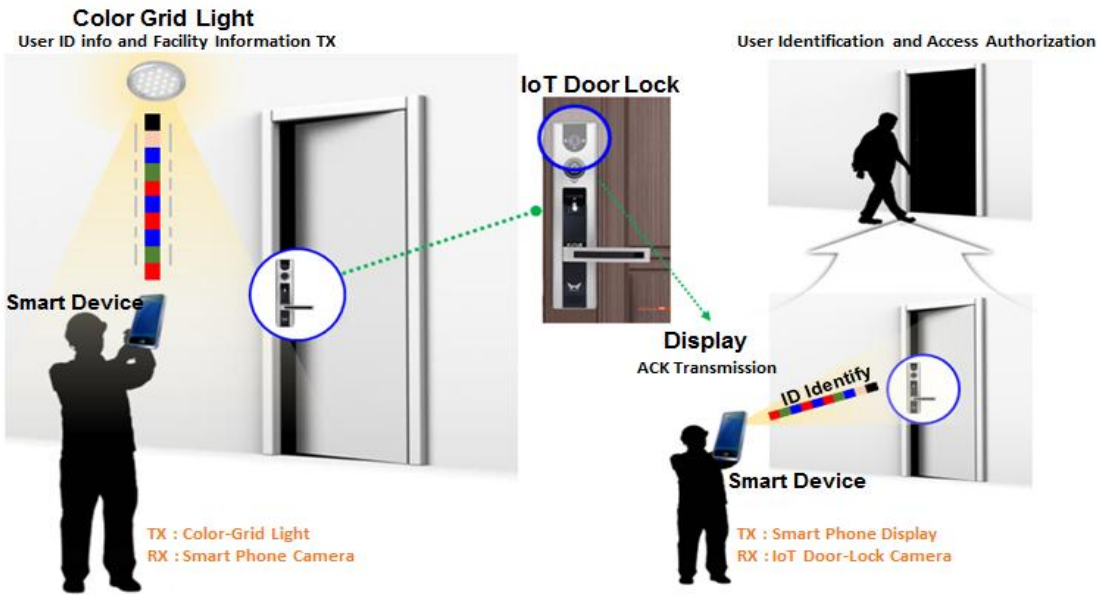
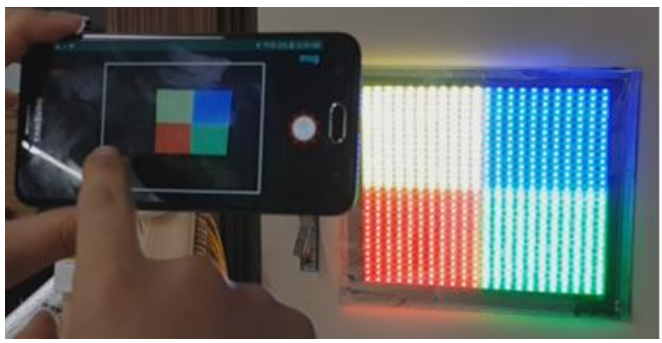


Figure 4. Proposed System Working Model

The camera based VLC receivers traditionally uses the computer vision based machine learning methods to decoder the color grid coded modulated pattern recognition. The machine learning based VLC receivers gives high computational complexity and the object recognition performance is poor compare to CNN based AI methods. So in this proposed approach uses the CNN based AI method to improve the color grid coded pattern recognition efficiency and latency. On this way the door access latency and efficiency are improved and give timely response for user door access.

5. Experimental Results and Analysis

To evaluate the proposed VLC based automatic door lock access control solution, IoT open-source LED controller based light source designed using Arduino Mega open-source hardware platform and IoT door lock camera designed using Raspberry Pi 3 open-source hardware platform with IP based camera source. The Arduino Mega with ESP8266 Wi-Fi controller used to design the IoT open-source color grid LED light is shown in Figure 5(a) and the Raspberry Pi open HW based IoT door lock with the camera is shown Figure 5(b). The open-source IoT controllers connected ACS central server using WiFi connectivity interface. The Android based smart device with custom developed application used for user authentication process. The python based application developed on raspberry Pi platform to receiver authentication status from the user smart device and control the open and close operation of the electronic door lock.



(a) IoT Open-Source LED Controller based Light Source

(b) IoT Door Lock with Camera

Figure 5. Raspberry Pi 3 based Signage Controller System

The proposed VLC camera receiver application uses the You Only Look Once (YOLO) framework to implement CNN algorithm to recognize the color Grid code in real-time. The proposed method CNN based OCC receiver gives 10fps average decoding performance implementation which improves 5 fps from the OpenCV based computer vision based VLC receiver implementation. Based on this performance, the average access control system authentication time is 500 milliseconds to open or close the electronic door. And provide 100% secure door lock access control using the proposed Open-source controller based door lock access control system solution.

6. Conclusion

In this paper presented the VLC based IoT open-source and AI based automatic door lock access control solution model using the building facility lighting infrastructure structure and camera built-in electronic door lock controller. The proposed automatic door lock access control solution provided the design and implementation details of IoT open-source controller based LED light source and door lock. The camera based

VLC communication using color Grid modulation through light source used for the authentication process and the camera based VLC receiver design using CNN based AI model with YOLO framework. Through the real-time experimental analysis, this proposed solution proves that VLC based door lock access control solution provide the secure and timely response for door lock control access in the building facility. The proposed solution can be realized with real-time door lock access with 5 meters distance from the door position and proves that's user friendly and a user does not need to be near the access controller interface to get door access and the performance improved with traditional access control system solutions.

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References

[1] Meera Mathew, Divya R S, "Survey on Various Door Lock Access Control Mechanisms," International Conference on circuits Power and Computing Technologies (ICCPCT), pp.1-3, 2017. DOI: 10.1109/ICCPCT.2017.8074187

[2] Pradnya R. Nehete, J. P. Chaudhari, et al., "Literature survey on door lock security systems," International Journal of Computer Applications, Vol.153, No.2, pp.13-18, 2016. DOI: 10.5120/ijca2016911971

[3] Neelam Majgaonkar, Ruhina Hodekar, et al., "Automatic Door Locking System," International Journal of Engineering Development and Research, Vol.4, No.1, 2016.

[4] Madhusudhan M and Shankaraiah, "Implementation of automated door unlocking and security system," International Journal of Computer Applications, pp. 5-8, 2015.

[5] Hteik Htar Lwin, Aung Soe Khaing, Hla Myo Tun, "Automatic Door Access System Using Face Recognition," International Journal Of Scientific Technology Research, Vol.4, No.6, 2015.

[6] Anuradha R.S, Bharathi R, et al., "Optimized Door Locking and Unlocking Using IoT for Physically Challenged People," International Journal of Innovative Research in Computer and Communication Engineering, Vol.4, No.3, 2016. DOI: 10.15680/IJIRCCE.2016. 0403120

[7] Chi-Huang Hung, Ying-Wen Bai, Je-Hong Ren, "Design and Implementation of a Door Lock Control Based on a Near Field Communication of a Smartphone," IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW), 2015. DOI: 10.1109/ICCE-TW.2015.7216992

[8] Am-Suk Oh, "A Study on Automatic Doorway Access Control System Including Server Based On Bluetooth Local Communication," International Journal of Control and Automation Vol.8, No.11, 2015. DOI: 10.14257/ijca.2015.8.11.07

[9] IEEE Standards, IEEE 802.15.7-2011. "IEEE Standard for Local and Metropolitan Area Networks-Part 15.7: Short-Range Wireless Optical Communication Using Visible Light," September 2011 [Online]. Available: https://standards.ieee.org/standard/802_15_7-2011.html. DOI: 10.1109/IEEESTD.2011.6016195

[10] IEEE Standards, IEEE 802.15.7-2018. "IEEE Standard for Local and metropolitan area networks--Part 15.7: Short-Range Optical Wireless Communications," April. 2019 [Online]. Available: https://ieeexplore.ieee.org/servlet/opac?punumber=8697196. DOI: 10.1109/IEEESTD.2019.8697198

[11] Jaesang Cha, Minwoo Lee, Vinayagam Mariappan, "VTASC – Light based Flexible Multi-Dimensional Modulation Technique for OWC," IEEE COMSOC MMTC Communications – Frontiers, Vol.13, No. 2, pp.39-43, 2018.

[12] Jaesang Cha, Vinayagam Mariappan, Sukyoung Han, Minwoo Lee, "Smartphone Color-Code based Gate Security Control," International Journal of Advanced Smart Convergence, Vol.5, No. 3, pp.66-71, 2016. DOI: 10.7236/IJASC.2016.5.3.66

[13] He, K., Zhang, X., Ren, S., Sun, J., "Deep residual learning for image recognition," In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, pp. 770–778, 2016. DOI 10.1109/CVPR.2016.90

[14] Sutskever, I., Vinyals, O., et al., "Sequence to sequence learning with neural networks," In Proceedings of the 27th International Conference on Neural Information Processing Systems, pp.3104–3112, 2014.