Angle-Based Localization and Security Enhancement in Optical Camera Communication

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Abstract— **In this article, we have designed an optical camera communication-based system that monitor the temperature and status of the valve position in the factory environment. We have used an AM2302 temperature sensor to collect the temperature data from the surrounding and transmit as an optical signal using LED. The image sensor received the optical signal and retrieve data based on rolling shutter effect of the camera. Neural network based LED detection is perform to find exact position of the LED in image sensor. Before data decoding, the output signal is processed using the unique key to enhance the security protocol. The entire process is performed in Python 3.8 environment.**

Keywords—optical camera communication, on-off-keying, monitoring, localization, security protocol.

I. Introduction

Optical camera communications (OCC) uses an image sensor as the receiver and light-emitting diodes (LEDs) as the transmitter and operates in the infrared or visible bands. OCC has a number of benefits, including low power consumption, low cost, and good security. OCC has enormous potential due of the ubiquitous availability of camera-mounted devices. Furthermore, OCC is less affected by noise and interferences [1]. However, OCC's main drawback is that it runs at a low data rate. The fundamental problem is that modern commercial cameras have poor sampling rates, as well as out of focus effect, uneven frame rate, and random block [2]. OCC's maximum data rate is limited to a few kilobits per second, making it ideal for low-rate applications including sensing, health care, localization, and device-to-device communications [3], [4]. The transmission range of OCC is determined by camera specifications as well as LED size. The channel parameters, synchronization between the camera and the LED, data transmission pattern, motion capture, modulation, and correct applications are the most important aspects to consider while utilizing OCC.

We create a neural network (NN) at the receiver to recognize the LED properly in both static and mobile situations. An LED array is often identified as a single LED in the literature; however, the suggested NN approach can identify each LED in the LED array. The NN can automatically learn from data and categorize big picture datasets with notable properties in numerous spatial layers via backpropagation. For the detection of the LED array and to assist mobility, many NNs have been given in the literature [4], [5]. They recreated the mobile condition, however, by continually moving a finger and blocking the specific LEDs [16]. Those approaches have a significant rate of error. In addition, we included a new security mechanism that improved the system's speed.

In this paper, our focus is to operate in continuous data reception by enhancing the system security and localization of LED and data storage to the cloud server. We have used neural network for LED detection and obtain the position of the LED inside the image sensor. Finally, we collected the data using on –off-keying demodulation after reconstructing the original stripe pattern.

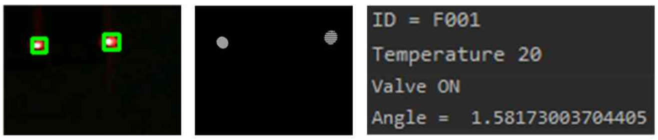
II. System Architecture

The system is mainly composite of two parts, transmitter and receiver. In the transmitter, the data is transmitted by employing a unique key with the input signal so the data is distorted. On the contrary, the image sensor receive the distorted signal as a form of image.

Algorithm 1 Data collection and Localization
Input: capture image
Output: Localization, ID, Status, Data
Initialization: unique key k, channel matrix H

```
execute image in gray scale
execute Gaussian Blur using kernel matrix
execute image binary
execute image erosion
execute canny edge detection
operate neural network-based LED Detection
if Pos(LED_1) = Pos(LED_2) then
    process data decoding
else
    if Pos(LED_1) > Pos(LED_2) then
        estimate relative angle
        status OFF
        process data decoding
    else Pos(LED_1) < Pos(LED_2) then
        estimate relative angle
        status ON
        process data decoding
    end if
end if
```

Identify the applicable funding agency here. If none, delete this text box.



(a) (b) (c)

Fig. 1. (a) NN based LED detection, (b) data collection using rolling shutter effect, and (c) status monitoing and localization.

The image is processed by employing in different steps. The algorithm 1 is shown the entire image processing steps with localization and data reception. After processing some image processing steps, the LED is detected using NN that is shown in Figure 1 (a). The LED is detected using a NN model, which also supports movement throughout the detection process. The location of the LED in the picture frame is compared to the location measured in prior frames when a frame is processed. The situation is regarded as movable if the position is altered. We used darknet_no_gpu.exe and OpenCV in Python to train 70% of the total captured photos for LED detection in this circumstance. We utilized an LED type named coco obj.name in the training procedure, with yolov3.weights as the weight configuration. Another configuration, yolov3-tiny obj.cfg, is used to identify the detected LED image in order to determine its precise location. The data decoding is perform after demodulating with the unique key. In Figure 1(b), the rolling shutter effect of the camera is shown. Finally, the output data with the localization information is illustrated in Figure 1 (c).

III. Security Enhancement

The data is transmitted by combining with another signal, as a result the characteristics of the main signal is changed. Therefore, data decoding will not been accurate by applying proper demodulation technique at the receiver. We assume that the input signal x is composite of number of symbols.

$$x = \{s_1, s_2, s_3, \dots, s_N\}$$

So in the image sensor receive the main signal as a form of array that can be represent as

$$r = Hx + n$$

where n and H are the noise and channel gain as a form of matrix. So enhancing the security protocol we have integrated an unique key k which is the element of matrix c. It is worth nothing that the values of c and x are within the range of 0-255. Now the modified x can be represented as

$$x' = 0.00196(x + c)c_I$$

Finally, the received output matrix can be written as follows:

$$r = Hx' + n$$

$$r = 0.00196H(x + c)c_I + n$$

When the camera receives the data, the noise and interferences can be removed using different filtering techniques. Finally, the data is demodulated using the following equation:

$$x = 510(r \times H^{-1})c_I^{-1} - c$$

IV. Conclusion

In this paper, we have designed a system that continuously monitors the temperature data and measure the relative position as a form of angle with respect to the other LED. The data is transmitted using a unique key and capture with a low frame rate camera (30 fps). The data is decoded using the OOK modulation technique in a Python environment. Finally, the data is sent to the cloud server for further analysis.

Acknowledgment

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References

[1] W. Liu and Z. Xu, “Some practical constraints and solutions for optical camera communication,” *Philosophical Transactions Royal Society*, pp. 378, 2020.

[2] M. F. Ahmed, M. K. Hasan, M. Shahjalal, M. M. Alam, and Y. M. Jang, "Design and Implementation of an OCC-Based Real-Time Heart Rate and Pulse-Oxygen Saturation Monitoring System," IEEE Access, vol. 8, pp. 198740-198747, 2020.

[3] N. Saeed, S. Guo, K.-H. Park, T.Y. Al-Naffouri, and M. S. Alouini, “Optical camera communications: survey, use cases, challenges, and future trends,” *Physical Communication*, vol. 12, pp. 1-17, 2019.

[4] M. F. Ahmed, M. K. Hasan, M. Shahjalal, M. M. Alam, and Y. M. Jang, “Experimental demonstration of continuous sensor data monitoring using neural network-based optical camera communications,” *IEEE Photonics Journal*, vol. 12, no. 4, pp. 1-11, 2020.

[5] M. Yoshino, S. Haruyama, and M. Nakagawa, “High-accuracy positioning system using visible LED lights and image sensor,” *IEEE Radio and Wireless Symp.*, pp. 439-442, 2008.

[6] M. Shahjalal, M.K. Hasan, M.Z. Chowdhury, and Y.M. Jang, “Smartphone camera-based optical wireless communication system: requirements and implementation challenges,” *Electronics*, vol. 8, pp. 913, 2019.