# Smartphone Camera-Based Indoor Positioning System Utilizing Optical Diffusion Filter

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## 1. Introduction

A user's indoor location is essential information for linking the many data circulating in the world of IoT, 5G, and AI. Positioning systems based on visible light communication have the potential to provide accurate navigation using existing smartphones, but the requirement for dual cameras [1] or limited communication distance [2] are barriers to realizing a positioning infrastructure. In this paper, we propose a positioning system that utilizes a cross-screen filter and a single camera that captures distant light sources.

## 2. System overview

Fig. 1(a) shows a block diagram of the proposed positioning system. The transmitter is installed at a specific location (*e.g.* ceiling) and outputs modulated 2D coordinate data, ($x_1$, $y_1$) and ($x_2$, $y_2$), as high-speed blinking LED. When a cross-screen filter is placed on the camera of the receiver (smartphone) to receive the blinking light, each light source is displayed as a spot on the image sensor, and the coordinate information output from each light source is simultaneously displayed as bright lines due to the rolling shutter effect. The receiver extracts the signals from the bright lines and decodes them to obtain the coordinate information of each light source. Then, the distance $d$ between the spots on the image sensor is calculated by the pixel distance and the pixel pitch, and the coordinate information and the distance between the spots are integrated to measure the distance between the transmitter and receiver $l'$ (Eq. 1), where $f$ is the focal length of the lens.

$$l' = \frac{\sqrt{(x_2-x_1)^2+(y_2-y_1)^2}}{d} \cdot f \qquad (1)$$

## 3. Experiment

The transmitter and receiver described in Section 2 were constructed and ranging experiments were conducted. A transmitter consisting of a microcontroller and two LEDs separated by 1,000 mm and a receiver consisting of a single board computer, a CMOS sensor, and a cross-screen filter were set up in an unlighted laboratory. 32-bit position information was Manchester encoded and output from the LEDs at a rate of 1 kbps. The distance between the transmitter and receiver was varied from 1,000 to 5,000 (mm).

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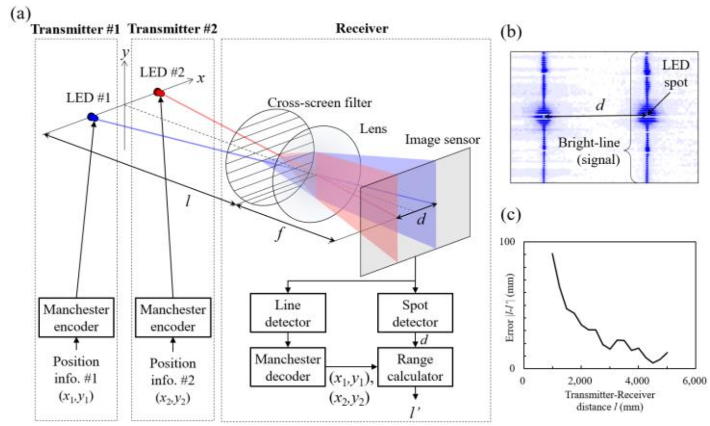


**Fig. 1** Proposed ranging system and experimental results; (a) block diagram of transmitter and receiver, (b) example of image sensor output, and (c) relationship between transmitter-receiver distance and error.

The experimental results are shown in Figs. 1(b) and 1(c). Fig. 1(b) shows the output of the image sensor. As shown in the figure, the position of the LED is indicated as a spot and the signal output from the LED as a bright line. Fig. 1(c) shows the results of measuring the distance between the transmitter and receiver. As shown in the figure, it was confirmed that if the distance between the transmitter and receiver is more than 2,000 mm, the distance can be measured with an error of 30 mm or less. The reason for the larger error when the distance between the transmitter and receiver is within 2,000 mm is thought to be the effect of lens distortion.

## 4. Conclusions

A positioning system that utilizes a cross-screen filter and a single camera that captures distant light sources was proposed. The obtained results suggest that the distance can be measured with a small error if the distance between the transmitter and receiver is large. This work is partly supported by JSPS KAKENHI Grant Number JP 21K19757.

**References**

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