A Proposal of High-Performance Method for Distance Measuring Sensor united with PSD

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Abstract. In this study, we propose a sensor system to improve the performance of distance measurement using multiple paralleled position sensitive detector (PSD) sensors. The PSD sensor uses a light emitted diode (LED) to illuminate an object and measures the distance to the object by the position on the PSD of the gathered light from the object. The proposed sensor system uses two symmetrically paralleled PSD sensors to increase the measuring distance extent and accuracy. Experimental results showed that the proposed PSD sensor system has an enlarged measuring extent, and has a measuring accuracy better than or equal to the conventional one.

Introduction

Recently, the development of robot system is rapidly advanced with the remarkable improvement of information processing technology. It is expected that the demand of robot system increases further because of falling birthrate and the aging society. Various kinds of robot systems have been studied such as help robot for senior citizens and handicapped persons to live safely and work robot for transporting and cleaning automatically at home and hospital, and several of them have been used practically[1-3]. In these kinds of robot systems, sensors for measuring distances are installed in order to catch objects or avoid from objects [4, 5]. To recognize objects precisely, high performance sensors are necessary. The existing distance sensors are millimeter-wave radar, laser distance measuring system, super sonic wave sensor system, distance measuring system using cameras and distance measuring sensor using position sensitive detector (PSD). However, millimeter-wave radar and laser distance measuring system are expensive and have large equipment size. And distance measuring system using cameras has to use computer to process images. In spite of super sonic wave sensor system having merits of cheap system cost and small size, it is impossible to recognize the target object around with multiple obstacles precisely because of the property of sonic wave. PSD sensor has merits of cheap system cost and small size too. It can recognize the target precisely by using a lens to focus the light from the target. For these reasons, PSD sensors are usually used at robot arms and the camera [6]. In general, the measuring extent of a PSD sensor is determined. It becomes larger as increasing the PSD sensor's size, but the measurement becomes impossible at short distances [7].

To solve the above problem, we propose a sensor system using paralleled PSD sensors. The proposed sensor system is cheap and has high performance of measuring distance and accuracy compared to the conventional PSD sensor.

Sensor System using Paralleled PSD Sensors to Measure Distance

Concept of Distance Measurement using a PSD Sensor [7, 8]. The construction of a PSD sensor to measure distances is illustrated as Fig. 1. The PSD sensor consists of a one-dimensional PSD with
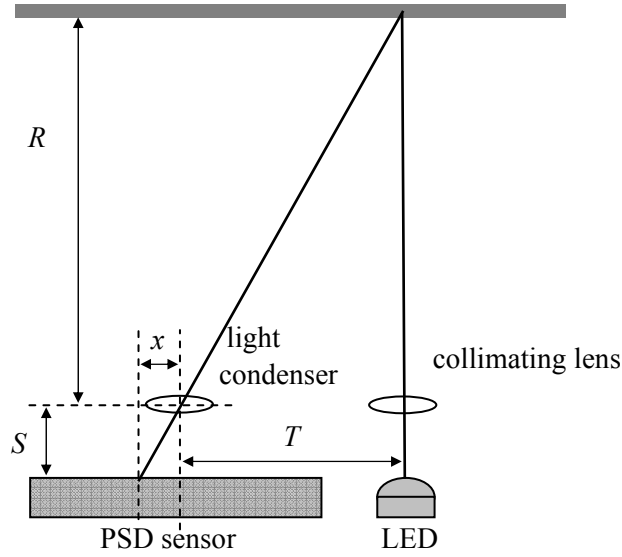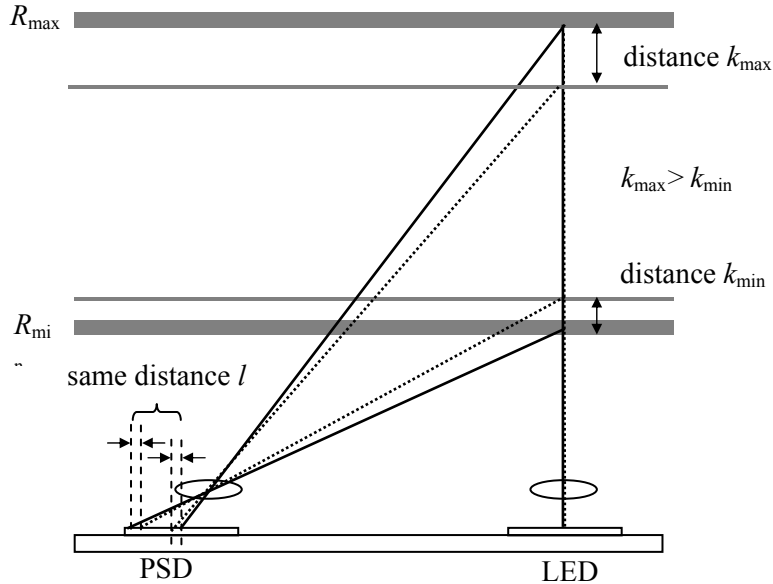
Fig. 1. Construction of PSD sensor.

Fig. 2. Illustration on the extent and accuracy of measuring distance.

a light condenser and a light emitted diode (LED) illuminating source collimated by a lens. The optical axis of the light condenser is placed at the center of the PSD. The collimated LED light is illuminated to an object perpendicularly to the PSD and the reflected light of the object is gathered to the PSD. The PSD outputs a voltage corresponding to the position of the gathered light on the surface of the PSD. This position is independent to the value of the gathered light and changes according to the position of the object. Suppose the distance between the position of the gathered light on the surface of the PSD and the optical axis of the light condenser as x, the distance between the optical axes of light condenser and LED collimating lens as T, and the distance between the PSD and the light condenser as S, then the distance R between the light condenser and the object is calculated as follows:

$$R = \frac{T \cdot S}{x} \tag{1}$$

For a general PSD sensor, T and S are determined, thus R is proportional to the inverse of x. Because the distance x is the position on the surface of a PSD, the value of x has a maximum that is a half of the
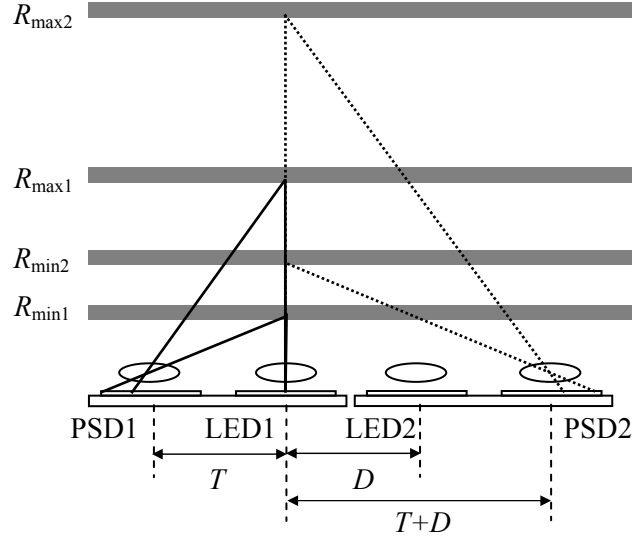
Fig. 3. Illustration of the two paralleled PSD sensor system on the measuring distance extent.

length of the PSD. Therefore, the measurable distance R has a minimum R_{min}. Also, the measurable distance R has a maximum R_{max} that depends on the measuring accuracy of the PSD and the desired measuring accuracy of the distance R. In addition, the measuring accuracy of distance R becomes lower as R increases. Figure 2 illustrates an image of the immeasurable distances outside the extent $[R_{min}, R_{max}]$. For details, see reference [7].

Construction of Sensor System using Paralleled PSD Sensors to Measure Distance. As described in the above section, a general PSD sensor has a determined measuring distance extent and the measuring accuracy of distance R becomes lower as R increases. We propose a sensor system using paralleled PSD sensors to improve the performance on the measuring distance and accuracy. Figure 3 shows the construction of the sensor system that two general PSD sensors are paralleled symmetrically. Denoting the PSDs as PSD1, PSD2, and the LEDs as LED1, LED2, respectively, PSD1 and PSD2 can receive the light from LED1 and LED2. Alternating the output of LED1 and LED2, the outputs of the PSDs can be divided into the LED1's period and the LED2's period by synchronizing the output signals of the PSDs to those of the LEDs. For convenience, we consider the performance of the PSD sensor system on the case with light source LED1 as shown in Fig. 3. Let the distance between PSD1 and LED1 be denoted as D, then the measuring distance extent of PSD2 is larger than that of PSD1 according to Eq. 1 because the distance between PSD2 and LED1 is larger than that between PSD1 and LED1. Also, the minimum and maximum of measuring distance of PSD1 are smaller than those of PSD2, respectively. In general, the maximum R_{max1} is larger than the minimum R_{min2} by controlling the distance D because there will exist immeasurable distance extent if not. For a distance R of an object, if $R_{min1} < R < R_{min2}$, we can use the measuring result of PSD1 while PSD2 is impossible for measuring distance. If $R_{max1} < R < R_{max2}$, we can use the measuring result of PSD2 while PSD1 is impossible for measuring distance. For the case of $R_{min2} < R < R_{max1}$, both PSD1 and PSD2 are possible to measure distance but the accuracy of distance using PSD2 is higher than that using PSD1. So we select the measuring result of PSD2 for $R_{min2} < R < R_{max1}$. By using this sensor system, higher measuring accuracy of distance can be achieved for object distance $R_{min2} < R < R_{max1}$ compared to the conventional PSD sensor and an additional measuring distance extent can be obtained. The total measuring distance extent of the sensor system is $R_{min1} < R < R_{max2}$ with measuring distance accuracy not less than that of the conventional PSD sensor. A maximum measuring distance extent of the PSD sensor system can be achieved by changing the distance D to let R_{max1} be equal to R_{min2}. The performance with light source LED2 is the same and the distance of another object illuminated by LED2 can also be measured with the same time.
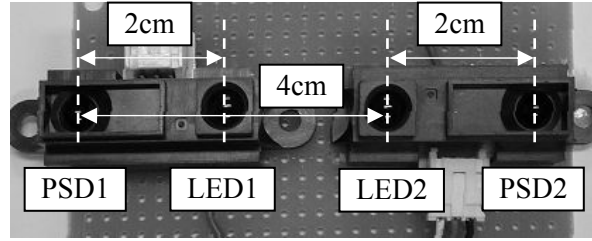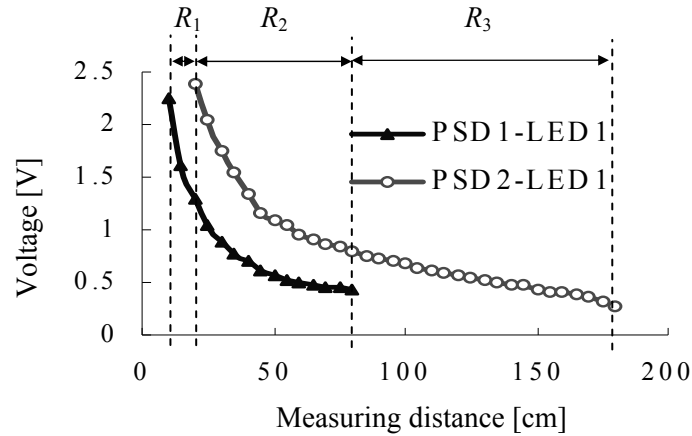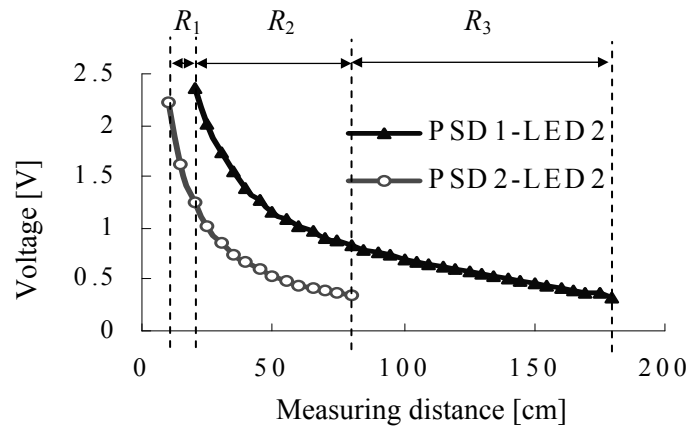
Fig. 4. Sensor system with two paralleled PSD sensor.

(a) PSD1 and PSD2 using light source LED1.

(b) PSD1 and PSD2 using light source LED2.

Fig. 5. Voltage dependences on the measuring distance.

Experiments

In the experiment, PSD sensors (GP2D12) fabricated by Sharp Corporation with measuring distance extent from 10 [cm] to 80 [cm]. The photo of the constructed sensor system is shown in Fig. 4. Two PSD sensors are set with 4 [cm] between the optical axes of the LED light sources. We measured the output voltage of PSD that corresponds to the position on the PSD and the differential of voltage on distance corresponds to the distance accuracy that a large absolute value of the differential of voltage has high accuracy. Figure 5 shows the voltage dependences on the distance from the object. The graphs of PSD1-LED1 and PSD2-LED2 are the conventional PSD sensor, and the graphs of PSD1-LED2 and PSD2-LED1 are the cases of PSDs using the light source LED of

another PSD. Because the distance D between PSD1 and LED2 (also PSD2 and LED1) is larger than that of the conventional PSD sensor, the measuring distance extent of PSD1-LED2 (also PSD2-LED1) is larger than the conventional one. The distance of the object can be divided into three distance extent R_1, R_2 and R_3. In the extent R_1, the measuring results of PSD1-LED1 and PSD2-LED2 are used so that the performance of the sensor system is same to the conventional PSD sensor. In the extent $R2$, the measuring results of PSD2-LED1 and PSD1-LED2 are used because the absolute values of their differential of voltage are larger than those of the conventional ones so that the performance of the sensor system has higher accuracy than the conventional PSD sensor. In the extent R_3, the measuring results of PSD2-LED1 and PSD1-LED2 are used that can be measured with measuring distance accuracy not less than that of the conventional PSD sensor but the conventional PSD sensor is impossible to measure the distance so that sensor system has additional measuring distance compared to the conventional PSD sensor.

Conclusions

We proposed a sensor system with paralleled PSD sensors to improve the performance of measuring distance. The measuring distance extent can be increased by using the PSD of the additional PSD sensor. Also, the measuring distance accuracy can be improved in the larger distance of the measuring distance extent of the conventional PSD sensor. We got the agreement with our experiments. It can be said the proposed sensor system is useful for the measurement of distance.

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