Artif Life Robotics (2010) 15:■■–■■
DOI 10.1007/s10015-010-0760-4

ORIGINAL ARTICLE

Akira Yamawaki · Takayuki Katakami · Yuhki Kitazono
Seiici Serikawa

A method using the same light sensor for detecting multiple events near a window in crimes involving intrusion into a home

Received and accepted: March 26, 2010

Abstract To combine robots with many sensor nodes on the sensor network is important for improving home security. To reduce the cost of such a system, it is desirable that each sensor node is very cheap and very small. The three events which occur to the window and the key when a thief attempts to intrude into a house are conventionally detected by different sensors. This article proposes a method of detecting all three events by using a simple light sensor consisting of an infrared LED and a photodetector. In the experiments, the light sensor shows the characteristic tendencies that can detect each event. This fact indicates that our proposal can realize one sensor node more efficiently than using different sensors.

Key words Light sensor · Detecting method · Sensor node · Multiple events · Home security

1 Introduction

To combine robots with many sensor nodes on a sensor network is important for improving home security.[1,2] To reduce the cost of such a system, it is desirable that each sensor node is very cheap and very small.

In the crime of intrusion into a home, three events occur, normally to a window.[3] The first is that there is a shock to the window. Then the window is opened. Finally the key is turned. Traditionally, these three events are detected by using multiple sensors. For example, a magnetic sensor detects the fact that the window has been opened and the key has been turned.[4] An impact sensor detects the shock to the window.[4]

A. Yamawaki (✉) · T. Katakami · Y. Kitazono · S. Serikawa
Graduate School of Electrical Engineering, Kyushu Institute of Technology, 1-1 Sensui-cho, Tobata-ku, Kitakyushu, Fukuoka 804-8550, Japan
e-mail: yama@ecs.kyutech.ac.jp

This work was presented in part at the 15th International Symposium on Artificial Life and Robotics, Oita, Japan, February 4–6, 2010

This article proposes a new method that uses the same light sensor to detect these three events. By using the same light sensor, the cost of buying several of the same sensors would be lower than the cost of buying a smaller number of different sensors. Instead of using different kinds of sensor, using a single sensor may lead to a smaller number of circuits. As a result, it is expected that the size and cost of the sensor node would be reduced. In addition, a light sensor is constructed of very simple components, i.e., an infrared LED and a photodetector. These are very cheap and can be obtained easily because many makers distribute them with the same characteristics.

The rest of this article is organized as follows. Section 2 describes the organization of the sensor node that employs our method using simple light sensors, and explains how it detects the three events. Section 3 describes the preliminary experiments. These experiments are to investigate whether the light sensor shows the characteristic tendencies that can detect each event or not. Finally, Sect. 4 concludes our article.

2 Proposed detecting method

2.1 Sensor node organization

Figure 1 shows a sensor node that employs our proposed detecting method using a light sensor. The method uses two light sensors (A and B) and two boards attached to the window, as shown in Fig. 1a.

In the light sensor, the infrared LED irradiates onto the boards at the window and the photodetector detects the infrared light which is reflected by the boards. Light sensor A irradiates onto the light-reflecting board when the window is closed. Thus, when the window is opened, the infrared light irradiated by light sensor A crosses the light-absorbing board. Light sensor B irradiates onto the top of the handle of the key when the key is locked. The size of the two boards is large enough to hide the sensor node from the outside light, as shown in Fig. 1b. In addition, the cover

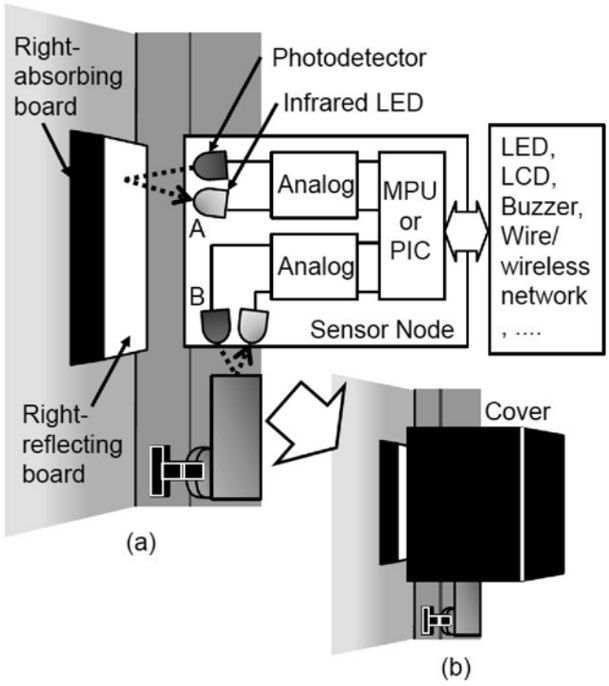

Fig. 1. Sensor node organization

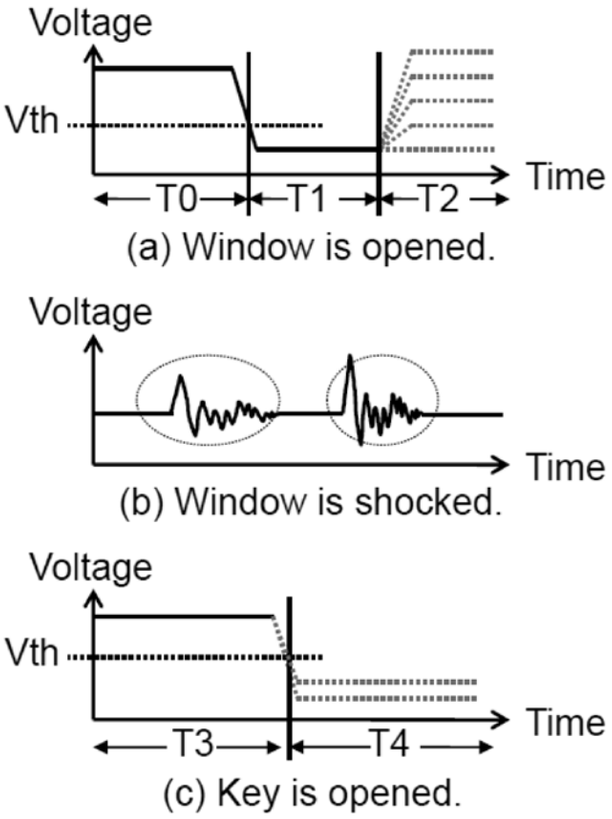

Fig. 2. Detecting methods

over the sensor node is used to obstruct the outside light as much as possible.

In the sensor node, the output voltage of the photodetector passes through analog circuits such as an amplifier, a filter circuit, and an A/D converter. The output voltage that has passed along the analog circuits is processed by the microcontroller. Then the microcontroller drives devices such as a buzzer or LED, etc., to alert the owner. This sensor node can also be connected to a sensor wire/wireless network to realize a more sophisticated security system.

2.2 Detecting method

When the closed window is opened, the output voltage of light sensor A will change, as shown in Fig. 2a. T0 indicates the period during which the window is closed and light sensor A irradiates onto the light-reflecting board. T1 indicates the period when the window is opened and the light sensor is crossing the light-absorbing board. T2 indicates the period when the window has been opened and light sensor A irradiates through the window. The change in the output voltage from T0 to T1 can detect that the window has been opened. In T2, the output voltage of light sensor A may be uncertain depending on the conditions outside, such as the weather and the time (day or night). Therefore, we prepare the T1 by using the light-absorbing board to make the drop in the output voltage clear.

When the closed window receives a shock, the window would vibrate.[5] As a result of this vibration, the distance between light sensor A and the light-reflecting board will change. Consequently, since the amount of reflected light will vary, the output voltage of light sensor A will change, as shown in Fig. 2b. Compared with the constant voltage without a shock, a shock to the window can be detected by the differences in the output voltage.

When the locked key is unlocked, the output voltage of light sensor B will change, as shown in Fig. 2c. T3 indicates the period when the key is locked. T4 indicates the period when the key has been unlocked. Compared with the period during which the key is locked, the distance between light sensor B and the handle of the key becomes longer. Therefore, the output voltage of T2 is smaller than that of T1. By using this fall in voltage, the fact that the key has been unlocked can be detected.

3 Experimental result and discussion

3.1 Experimental environment

To confirm that proposed method can really detect these three events in the crime of intrusion into a house we have developed a prototype.

In the prototype, we have used a TLN110 for the infrared LED and a TPS611 for the phototransistor. The light-reflecting board is corrugated paper whose surface is shiny white. The light-absorbing board is constructed of the same corrugated paper with a black surface.

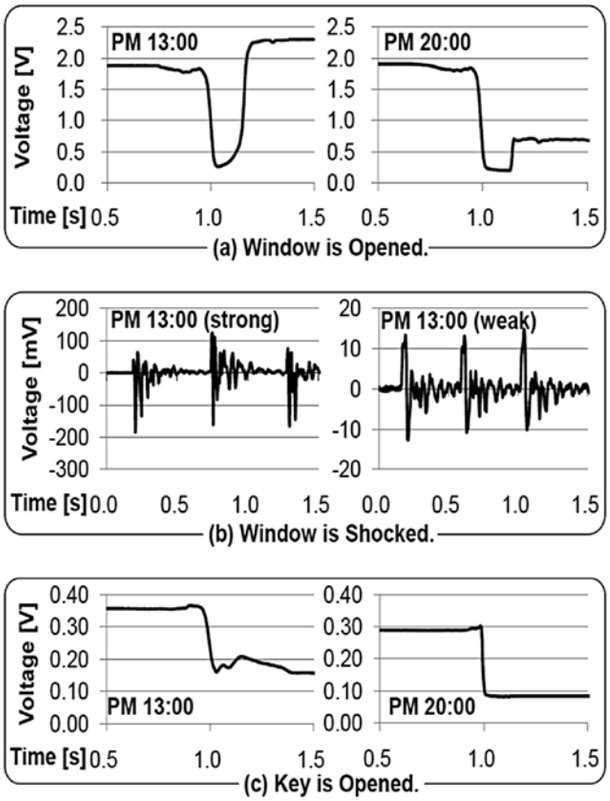

Fig. 3. Experimental result

The prototype was set near a south-facing window in the laboratory. We set the distance between light sensor A and the light-reflecting board to about 0.8 cm. The distance between light sensor B and the top of the handle of the locked key was set to about 1.5 cm.

We made a cover of corrugated paper and painted the inside of the cover black. The chink between the cover and the light-reflecting board was about 0.2 cm. The chink between the cover and the handle of the locked key was about 1.0 cm.

We took measurements at 0800 h, 1300 h, 1700 h, and 2000 h on a sunny day. In the case of a shock to the window, we extracted only the differences in the constant voltage, and removed the DC by the capacitor.

3.2 Result and discussion

3.2.1 Window is opened

Figure 3a shows the results when we opened the window 10 times. The output voltages of light sensor A when the window is closed were 1.97–2.03 V. In contrast, the output voltages when light crossed the light-absorbing board decreased to 0.19–0.26 V. This fact indicates that differences in the voltage can detect that the window is being opened.

3.2.2 Shock to the window

Figure 3b shows the results when we gave the window a shock 10 times. Most thieves break the window around the key when breaking into a house. Therefore, we gave the shock around the keyhole from outside the window. The shocked area was within about 20 cm radius from the keyhole.

As shown in Fig. 3b, there are clear differences in the output voltage between the two cases. For example, when the window has not received a shock, the peak-to-peak voltages of light sensor B are lower than 0.5 mV. In contrast, when a shock has been given to the window, the voltages are 12–310 mV. Thus, the shock to the window can be detected by using the differences in the constant voltage.

3.2.3 Key is unlocked

Figure 3c shows the results when we unlocked the key 10 times. The output voltages of light sensor B were 0.29–0.37 V when the key was locked. In contrast, they were 0.08–0.14 V when the key was unlocked. By using this voltage drop, it is possible to detect that the key has been unlocked.

4 Conclusion

Using a simple light sensor, we have proposed a method of detecting the three most common events that occur to the window and the key in the crime of intrusion into a house. Through a preliminary experiment, it has been confirmed that a simple light sensor can detect these three events as expected. This fact indicates that our proposal can realize a single sensor node which is more efficient than using different sensors.

In future work on putting our method to practical use, we will decide on the threshold voltages and signal processing methods by giving stimuli which correspond to a real crime

References

1. Kim YG, Kim HK, Yoon SH, et al. (2006) Home security robot based on sensor network. Proceedings of the SICE–ICASE International Joint Conference, pp 5977–5982
2. Kim T, Ha YG, Kang J, et al (2008) Experiments on building ubiquitous robotic space for mobile robot using wireless sensor networks. Proceedings of the 22nd International Conference on Advanced Information Networking and Applications, pp 662–667
3. Ueno Y, Kawasaki Y. Oshima R (2007) About security measures of fittings for plural means of the invasion crime (Part 1). The security performance and cost of windows (in Japanese). Summaries of Technical Papers of the Annual Meeting of the Architectural Institute of Japan, pp 749–750
4. Mitsuhashi K, Torimiya N (2002) Home security system "BBee" (in Japanese). Annu Design Rev Jpn Soc Sci Design 8(8):26–29
5. Mizuki N, Aratani S, Hidenori O, et al (2003) Experimental study of glass strength against shock wave loading: stress generation of float glass plates (in Japanese). J Ceramic Soc Jpn 111(1297):674–679