Design and Implementation of a Ubiquitous Optical Device Controlled with a Projector

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ABSTRACT

We recently have seen illumination using Light Emitting Diodes (LEDs) on the street. The current illumination is difficult to control of flexibly and dynamically. In response to this problem, we propose a method controlling numerous LEDs collectively, dynamically, and flexibly by using a projector and small devices with optical sensors. We designed and implemented a small device to achieve our mechanism, which has an LED, an optical sensor, and a microcomputer to react to the light illuminated from a projector. Moreover, it has functions to self adjust the threshold and recognize optical commands, which are required for collective control. We discuss how effective our proposed device was in a study to evaluate it and in field tests done at actual events.

Categories and Subject Descriptors

B.4 [Information Systems Applications]: Input/Output and data Communicatons; B.1.5 [Hardware]: Control Structures and Microprogrammimg—Microcode Applications

General Terms

Design

Keywords

LED, illumination, ubiquitous device, infrared, projector

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1. INTRODUCTION

Light Emitting Diodes (LEDs) have advantages of long life, low for heat generation, and low in power consumption, and they have recently been used various purposes and daily life, such as signatures, signals, and streets lighting. Illumination especially that of such as Christmas trees decorated with LEDs increases its expressive power achived by technological advances in lighting devices[1][2][3]. However, the behavior of conventional illumination is mostly limited to simple patterns such as repeated blinking. This means that it is difficult to control numerous LEDs cooperatively to depict the complex animation and characters with large-scale illumination. Wireless communications technology[4][5] can be a the solution to achieving a flexible operation with such illumination. However, to attain these kinds of applications, devices have to identify their position and people have to program them taking into consideration the synchronization of all LEDs and arranging LEDs carefully in predefined position . It is difficult to control these devices via a wireless network. To solve this problem, we constructed a ubiquitous optical device that was collectively, dynamically, and flexibly controlled by using a projector. The device we propose has functions that automatically adjust the threshold for control and recognize several optical commands; they are required for actual use in various environments.

This paper is organized the follows. Section 2 describes our proposed method. Section 3 describes the requirements our device needs for use. Section 4 explains its implementation and functions. Section 5 and 6 explain our evaluation and field test on the device. Section 7 discusses related work. Section 8 presents our conclusion.

2. PROPOSED METHOD

The proposed device has an optical sensor, an LED, and a microcomputer, as seen in Fig. 1. When visible lights or infrared rays are sent to the optical sensor, the microcomputer

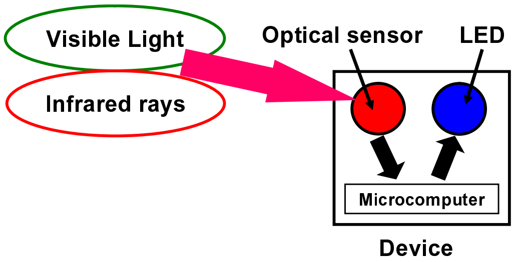


Figure 1: A device for collective control

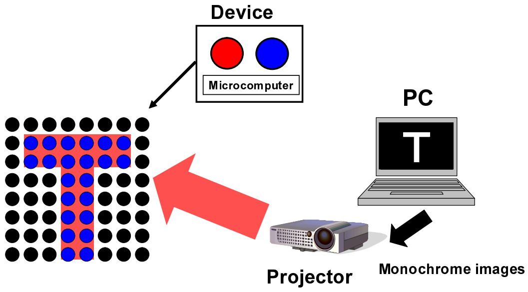


Figure 2: Cooperation among numerous of LEDs

controls the LED by monitoring the sensing data. Because the LED is controlled by lights, it is not necessary to install programs into the device. Since we can also control the LED by infrared rays that are invisible, it is autonomously controlled.

Figure 2 shows the setup for our device. Using a projector to control the device, we can flexibly control it. As seen in the figure, the device display PC and projector images or MPEG/Flash movies by projecting monochrome images to the devices. The LEDs in the white part of the image are turned on and the others are turned off.

To achieve the same functions with conventional methods, users must program complex controls taking the position of all devices into consideration and their synchronization. Therefore, , it is difficult to dynamically change behavior using conventional methods and some part of hardware problems may cause serious errors in the whole system. However, our method employs a simple way of controlling the devices; we only have to prepare the images and do not need to program complex behaviors. We can change the illumination patterns in response to changes in environmental conditions. Moreover, since our method has the advantage being of independent of location, we do not need to consider the position of any devices and they can be attached to uneven surfaces or sloping surfaces. From these characteristics, our method is well suited to the illuminating objects such as Christmas trees.

3. REQUIREMENTS

Our device needs to satisfy the following requirements before the use described in the previous section:

- Small and light device

  We need to use the proposed device for large scale illumination that displays characters and images. To apply many devices to various kind of illumination, they should be small and lightweight.

- Self-calibration function

  Because the light intensity that the device receives differs according to the angle and distance from the projector, the appropriate threshold for it to recognize the light is different. Moreover, in the same environment, each angle to the projector varies according to various arrangements. For example, when we use our devices on a Christmas tree, the distances and the angles are different on all devices because of the the surface is round. Therefore, the system needs to automatically configure the threshold to reduce the setting time.

- Mode-changing function

  Our device should have many modes such as recording, playing, self adjustment, and a normal mode that reacts to the light immediately. If the change of modes is controlled by switches on the device, users have to operate switches on all devices to change the modes . Therefore, we propose a function for recognizing an optical commands on the device to change the mode. The optical commands consist of lighting patterns.

- Recording the blinking patterns and playing the stored patterns

  Our system may be used in situations where we cannot use a projector because of environmental restrictions. Consequently the device needs a function for recording and playing the blinking patterns of LEDs.

4. DESIGN AND IMPLEMENTATION

We implemented a prototype device. Figure 3 has a snapshot of the prototype, and Fig. 4 shows its circuit diagram. The circuit board was 1.0 (W) $\times$1.5 cm (L). We used Atmel's ATtiny85 as the microcomputer, and the TT Electronics OP520 as an optical sensor. Because we used a phototransistor as the optical sensor, the prototype could detect both visible light and IR. Generally, illumination was carried out in a dark environment. Lights from the projector prevented us from seeing LEDs blinking. To solve this problem, we could have used an IR projector or IR filter to cut off the visible light.

4.1 Control LEDs on devices

We could flexibly control the LEDs on the devices with the projector. The devices projected images or MPEG/Flash movies by projecting monochrome images to the devices. The LEDs in the white part of the image were turned on and the others were turned off.

4.2 Recording and playing

We implemented a function to record and play the blinking patterns of LEDs. The patterns were recorded to the electronically erasable programmable read only memory (EEPROM) built into the microcomputer. The recording/playing frequency was 20Hz, and the device could store patterns for 13 min.

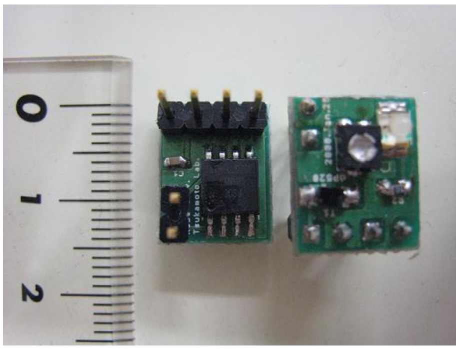


Figure 3: Ubiquitous optical devices

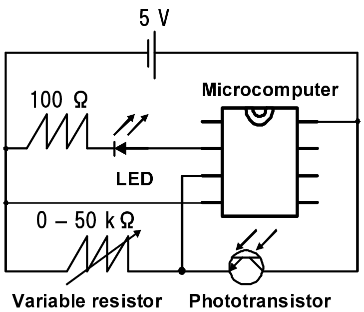


Figure 4: Circuit diagram

4.3 Self calibration

Figure 5 shows the flow for the self adjustment function. First, the device obtains the value of the light sensor in receiving a projected black image. The device stores the average value of 100 trials as a *base*. The LED is on the device turned on during this step, and when the procedure for this step is finished, the LED is turned off. Then, the device waits to receive a projected white image. If the device receives a white image that means the sensor has detected a bright color ; it then starts blinking its LED and goes to the next step. If the device cannot detect light for 30 s, it turns off the LED and the device is not used. In the next step, the device obtains the value of the sensor in receiving the projected white image, and calculates *top* in the same way as *base*. Finally, the device calculates the threshold from *base* and *top* as $thethreshold = (top - base)/4 + base$, and turns off its LED.

4.4 Mode-change function

We also implemented a mode-change function achieved by recognizing optical commands that identify time-series monochrome images as commands.More concretely, when the device detects white/black images, it adds the value to the queue for command recognition one after another. Next, if there is a pattern in the queue that matches the predefined commands, the device executes the command. We implemented the commands for all LEDs to turn on and off and start blinking. Figure 6 shows the binary format for the commands. A command consists of 8 bits, whose first 6 bits is the header and the others express the Command ID. The

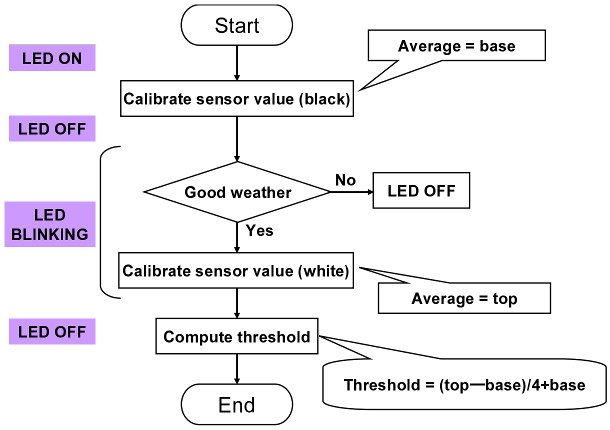


Figure 5: Flow for calibration

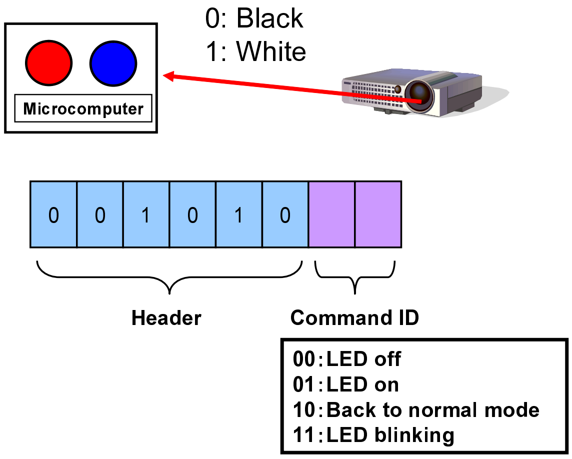


Figure 6: Command format

length of 1 bit was 800 ms, and the sampling frequency on the device was 200 ms.

5. EVALUATION

We conducted an evaluation to investigate the recognition rate in changing the distance and the angle between the prototype device and a projector. Figure 7 has a snapshot of the experimental set up. The experiment was conducted in a room with the light turned off after sunset. We used the PLUS U5-112 from PLUS Vision, U.S.A as the digital projector, and the IR76 from Fuji Film, inc, Japan as the IR filter to cut off the visible light from the projector. We alternately projected a white image and a black image onto nine devices arranged on a board, and we recorded the number of reactions for correct, flickering, and incorrect reactions. We changed the distance from the board to projector 1.0 m, 1.25 m, 1.5 m, 1,75 m, 2.0 m, 2.25 m, and 2.5 m, and the angle of the board to the projector to $0°$, $30°$, $60°$ as shown in Fig. 8. Moreover, we compared the prototype with a device that did not have a self adjustment function in the same experiment.

We calculated the recognition rate in two ways. The first

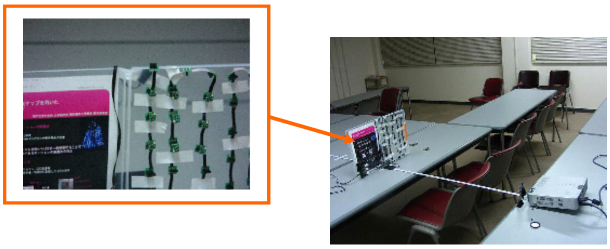


Figure 7: Snapshots of experiment

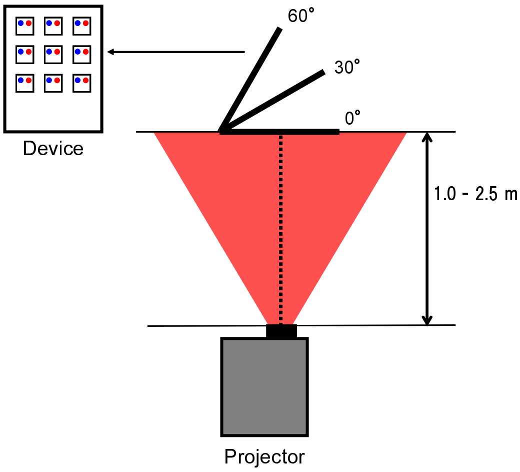
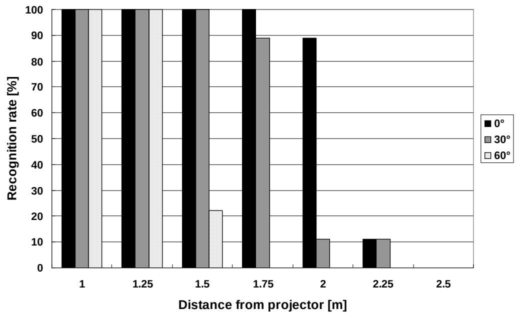
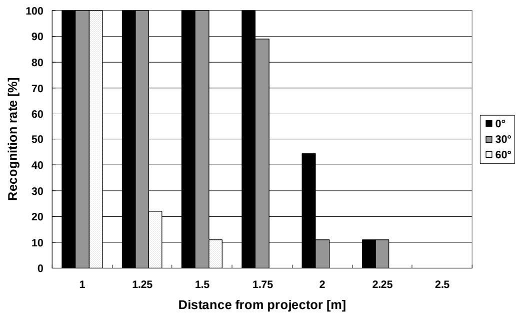


Figure 8: Configuration of experiment



(a) Self adjustment to threshold



(b) Fixed threshold

Figure 9: Recognition rate in changing distance and angle (1)

was where flickering devices were counted as correct reactions (Fig. 9), and the second was where they were not counted (Fig. 10). In total, the recognition rate with the self-adjustment function was high at all angles and all distances. This means that self adjustment effectively occurred in the proposed device. However, the recognition rate decreased at long distances, and it decreased 0% at 2.5 m. This is because there are few infrared rays in the light of the projector and their quantity decreased at longer distance. In addition, we confirmed that the differences in angles greatly influenced the recognition rate. This is because the optical sensor had directivity and the threshold should had to be changed according of the direction to the light source. We clarified that the automatic adjustment worked well by comparing the self adjustment to the threshold in result between Fig. 9(a) to the threshold in Fig. 9(b).

From the results in Figs. 9 and 10, the number of flickering devices increased as the distance increased, especially when self adjustment was not used.

We also conducted the same experiment with an infrared ray projector. We used the L-light from Sun-Mechatronics ,japan as the infrared ray projector (Fig. 12). We projected the light on and off nine devices arranged on a board and we recorded the number of correct reactions. We increased the distance from 5 to 25 m.

Figure 11 plots the results for the experiment with the infrared-ray projector. The recognition rate is 100% as far as 20 m, and reaches 0% at 25 m. The results reveal that we can control LEDs from longer distances by using a projector that has stronger infrared rays.

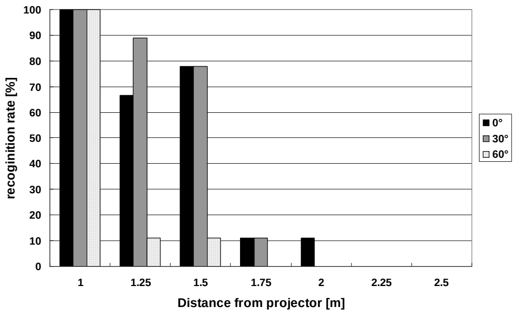
6. ACTUAL USE IN AN EVENT

We used the prototype on the stage at *the Kobe Luminarie* [9] on December 8th and 9th, 2007. *The Kobe Luminarie* has been held annually since December 1995 as a memorial to the loss suffered by victims of the Hanshin-Awaji Earthquake and is a symbol of reconstruction. Figure 13 has a snapshot of the stage and Figure 14 shows the stage arrangement. We set up 300 devices on the surface of a tree whose height was 180 cm, and it was arranged 2 m from the projector. We used the same projector and IR filter as that in the experiment. We projected a monochrome Flash movie for one minute to the stage, and we confirmed the characters and animation had been reproduced correctly.

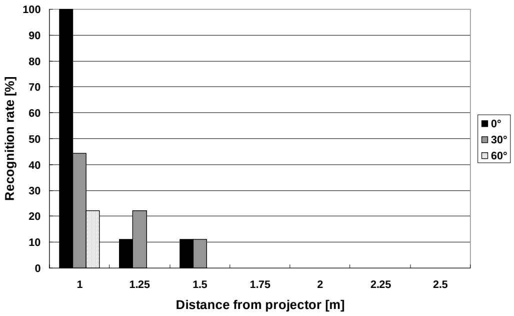
A few devices blinked incorrectly because of the influence of outdoor environmental lights, such as street lamps with strong infrared rays. This problem could be resolved by further improving the device such as changing the kinds of light sensors and narrowing down the bandwidth that the sensors detect in the projected light.

7. RELATED WORK

There are several kinds of accessories and items available that enable flexible illumination, and research has been done



(a) Self adjustment to threshold



(b) Fixed threshold

Figure 10: Recognition rate in changing distance and angle (2)

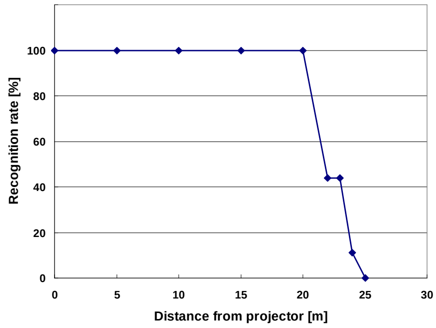


Figure 11: Recognition rate by infrared projector

Figure 12: Infrared projector

to control LEDs diametrically. An e-textiles construction kit[1] that consists of an electronic unit can be stitched on to cloth, achieving many kinds of wearable fashions. Bloom accessories are[3] is a sensor-enabled accessories using LEDs that can be controlled remotely by ultrasonic communication. They can change color and brightness dynamically. Incremental programming [2] is a method of controlling multiple LEDs to create art works or wearable fashion. It can control LEDs dynamically by using a wireless network. Although they increase the express power of illumination, they cannot be applied to large-scale illumination. Research on the presentation of information with projectors includes the I/O Bulb[6], iLamps[7], and Projector-Guided Painting[8]. They only use a projector to send information, and they do not take into consideration the collective control of a large number of LEDs with invisible light.

8. CONCLUSIONS

We have proposed a ubiquitous optical device to collectively control LEDs with a projector. Our device has an optical sensor, an LED, and a microcomputer, and reacts to projected light. Moreover, we implemented a function for recording and playing blinking patterns of LEDs, a- self adjustment function and a mode-change function by using recognition of an optical commands. As a result of evaluation, we confirmed our proposed device was effective.

In future, we plan to improve our device to recognize various kinds of commands at longer distance, and to be less affected by outdoor light.

9. ACKNOWLEDGMENTS

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Figure 13: Snapshot of using our devices at $KobeLuminarie$

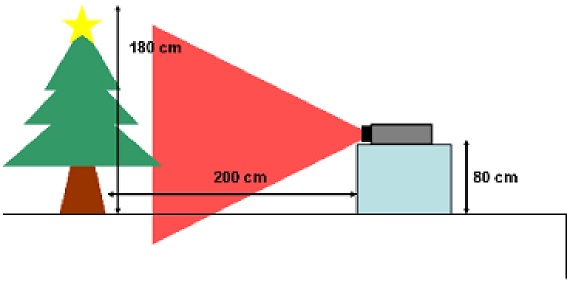

Figure 14: Stage arrangement

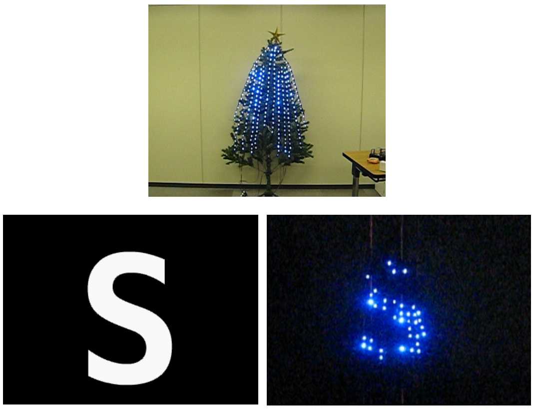

Figure 15: Reproduction of a letters

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