inter-glow

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Figure 1: Users control lights and explore relationships of characters

Abstract

Inter-glow is a system that facilitates close interaction and communication among users in real space by using multiplexed visible-light communication technology. By shining light on an object containing an embedded photo sensor, users can get information about the object. In addition, several users can communicate with each other intimately by shining light on the object at the same time.

We built a prototype to demonstrate the technology. In our prototype, when users point their lamps at the table in a miniature living room, the system can recognize which lamps are illuminating the table. According to the combination of illuminating lamps, the system produces the family conversations.

Keywords: visible-light communication, pervasive computing, intelligent space, interactive art.

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1. Introduction

Light means information for human beings. Since early times, human beings use light to receive information: for example, we use fire to brighten a dark environment so that we can navigate. We also control light to communicate a message, for example, using light Morse-code at night. In contrast, light do not have meaning for computers.

Recently, a computing technique that utilizes visible light as input data called Display-Based Computing (DBC) has been proposed [1]. DBC allows computers to comprehend and make decisions by using a projected image as input. Machines distinguish the differences of signals from a projected image by colors or brightness. Though these can also be recognized by to human eyes, such a projected image is unnatural for human beings.

On the other hand, visible-light communication (VLC) [2] technology has received a lot of attention recently. By including information signals in a generic illumination, VLC is unnoticeable to humans and makes it possible to have a broadband communication in everyday living space. VLC technology uses high-brightness white LEDs, and transmits data by flickering the LEDs at a speed undetectable to the human eye [3, 4]. The invention of white LED led to utilization of VLC in life space. VLC is advantageous because it has the potential to become a ubiquitous technology. We can use the lighting infrastructure that already exists around us for communication without having to changes the environment.

By controlling light to transmit information, computers can also get information from the environment, as humans do. Using this technology, the authors expect that we can interact intuitively with computers. Recently, pervasive computing [5] has been proposed to transform environments, such as urban space and public space, into intelligent spaces saturated with computing and communication capabilities [6]. In this trend, this study presents the possibility that we are able to interact naturally in a pervasive computing space by using light that fills the space naturally.

2. Basic design

In this paper, we propose a system that enables intuitive interaction with intelligent space by using VLC. There are three requirements for this system:

1. Light is the input in this interactive system. At the same time, the light has to look like any other light.
2. If the system receives light from several sources, it has to able to distinguish the sources. It is preferable that the system can distinguish many light sources simultaneously.
3. The response has to be fast.

First, we use light as the input of this interactive system. It is an advantage of VLC that we are able to understand a position where information exists. Because we can figure out easily the position of the sorce of the information, we handle it intuitibely in an interactive system. At the same time, our system must use light that is similar to existing illumination to facilitate installation in existing living spaces. Furthermore, the brightness of the must not change with time.

Secondly, the system has to distinguish the input sources if it receives light from several sources. For example, the system should be able to simultaneously receive environmental information from environmental lighting and a user's information from his/her device. In addition, multiple users in the same space should be able to interact with the same system at the same time. Furthermore, the system support expandability of space. The system should provide a rich user experience by creating different reactions depending on the type of input lights. By using an action, such as overlapping light sources, the system promotes the participation of multiple users and cooperation between them.

Third, the response has to be fast. The system has to respond to changing situations quickly in order to provide a natural and comfortable interaction. In addition, if the situation changes, the response must not be sudden but smooth.

To satisfy these requirements, we consider using multiplexed system of visible-light communication. We use white LEDs as the light source, and information is transmitted by controlling the flicker rate of the LEDs. Human beings cannot see the flickers of visible light if it is flickering at a rate of more than 60Hz. Therefore, flicker rate has to be equal to or higher than this period.

In order to recognize simultaneous light inputs, we have considered the Time Division Multiplexing (TDM) technique, which is often used for multiplexing digital transmissions. By using TDM in VLC, the more the number of light sources which the system can distinguish at the same time, the longer the time when a light source is unlit. Thus, the more the number of slots, the darker the light becomes. Since this spoils a property of LED as illumination, it is unsuitable to use TDM. In addition, it becomes difficult to further increase the number of light sources.

Therefore we focus on multiplexing with frequency. Since the color of the light must not be changed, it is unsuitable to change the frequency of the light. Therefore we emit light by Pulse Wide Modulation (PWM) control of 50% duty ratio and change one period of length of square wave in every light source. And the system analyzes a frequency ingredient of intensity of light input into a photo sensor. When users shine lights from several sources, the system can distinguish the sources. A new sources can be added freely if the pulse frequency of the new source is not a multiple of the pulse frequency of any existing source. In addition the brightness of all the lights remains constant at half the brightness of an original source of light thus this method is robust in an environment with disturbance and the response is very fast.

By using the VLC that multiplexes by pulse frequency of light for an interaction, we can input and receive information intuitively. If we set appropriate reactions to inputting several lights together, the system promotes cooperation among several users.

3. System design: “inter-glow”

We describe an interactive art installation called "inter-glow," an implementation of the proposed system. We design our installation to look like a miniature living room. The system configuration is illustrated in Figure 2 and the block diagram in Figure 3.

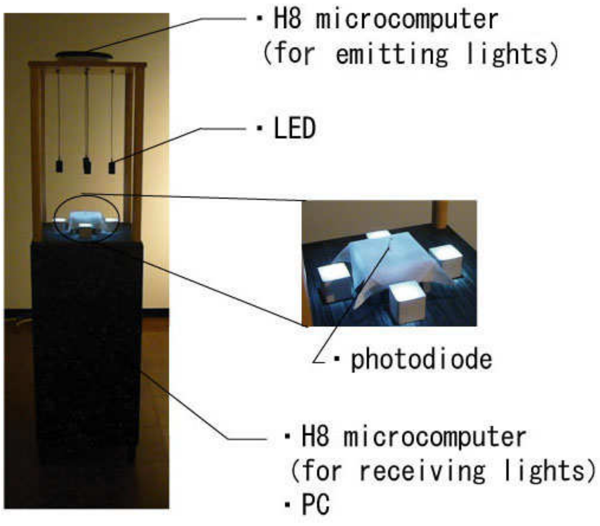

Figure 2. System configurations

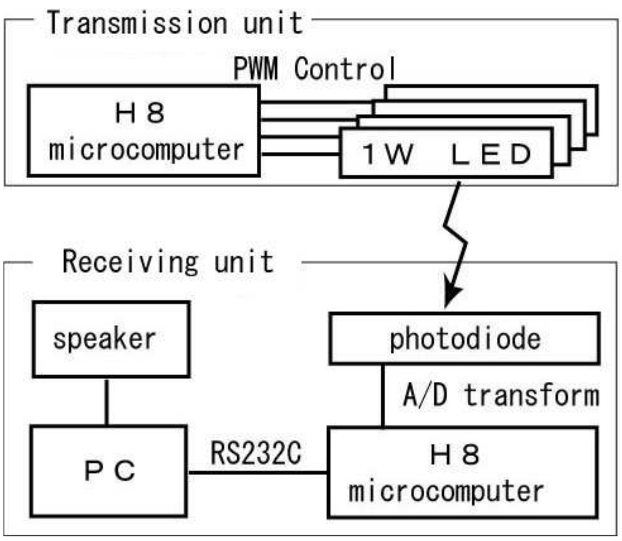

Figure 3. System block diagram

At the transmission unit, we use an H8 microcomputer to control the flicker rate of the LEDs. In our installation, we flicker four LEDs each at 120Hz, 150Hz, 200Hz, and 250Hz. We use super high brightness 1W white LED and design the system to function at a certain level of illumination and external light.

At the receiving unit, the H8 microcomputer converts the intensity of light, which is received by a photodiode, into a digital value. Afterwards, it sends the value to a PC. We have designed an algorithm that computes fast Fourier transform (FFT) with 512 samples and removes noises. Using this FFT, the PC analyzes a frequency ingredient of light flickers and distinguishes which LEDs are being manipulated by the users. Depending on the combination of lights being input (16 patterns), the PC plays back an appropriate sound.

We implemented a novel system which plays back conversations among four family members depending on the combination of input light sources. In this system light represents human existence. Through the simulated living room where people gather together, users control the light, make characters interact with one another, and explore their relationship of them. We name our system "inter-glow" after the communications of glow-flies which communicate using light.

A monologue of a character is played back when one light is detected, while a conversation among characters is played back when multiple lights are detected. Moreover, overlapping lights is equivalent to making characters having a conversation, and conversations are played according to the combination of lights. If users input other lights during a conversation, the characters assigned to these new sources participate in the conversation instantly. If a particular light becomes inactive, the character it represents drops out of the conversation. In such a case, the system is designed to continue natural conversation. We set multiple conversations for each one of 16 different combinations. There are 40 conversations, and some stories consist of one of these. One user can not listen to all the conversations without other's cooperation because it is difficult to operate four lights at the same time.

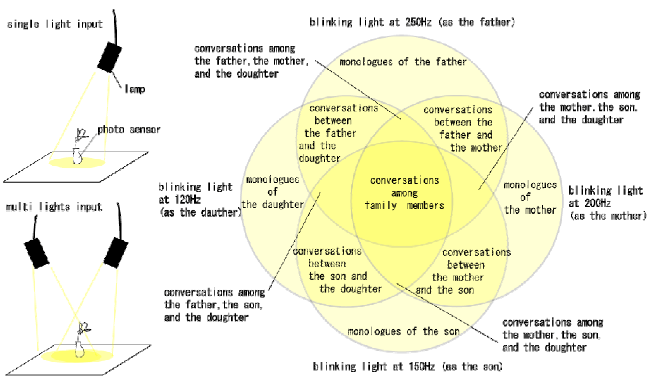

Figure 4. combination of lights and conversations

4. Experiment

We exhibited the work on "iii exhibition 6" which was held at the Univ. of Tokyo in December, 2006. The system's durability was demonstrated by its continuous operation all the time over one week. During the exhibition, we observed the reactions of more than 500 visitors. The exhibition scenery is illustrated in Figure 4.

The ease of controlling the operations by light and making characters having conversations by overlapping lights received positive feedback from many users. So did good responsiveness. In addition, some users pointed out that they felt the presence of the characters more strongly by using light, compared to using things like dolls. Sometimes several users control more than two lights each while communicating with each other because this system is effective enough to promote communication and cooperation among users.

Figure 4. Cooperation between two users

5. Conclusion

In this paper, we proposed a system that enables people to interact intuitively in an intelligent space by using visible-light that transmits information by multiplexing VLC. We created an interactive art installation called "inter-glow," as an implementation of the proposed system. "inter-glow" allows uers to explore interactively the relationships between characters by controlling lights in a miniature living room. We had exhibited and showed the effectiveness of the proposed system by observing the reactions of more than 500 users.

In the future, we plan to expand this system to a real size room, in which we can interact with spaces and others in the same space naturally without being consciously aware of the lights as a medium. There is also the potential of using this technology as an effective interactive museum guide with using an instruction effect of illumination together.

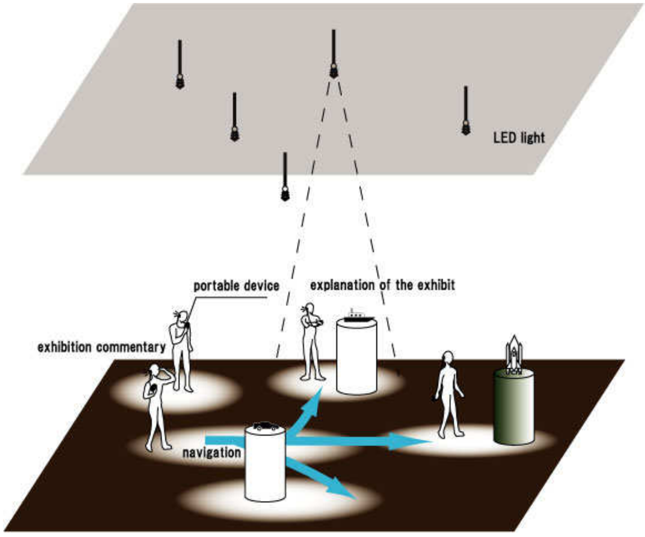

Figure 5. Museum guide with our system

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