ID-embedded LED Lighting Technology for Providing Object-related Information

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The spread of smart devices and the expansion of the communications environment for accessing the Internet have made it possible for users to obtain information whenever they want and wherever they are. It is now commonplace for them to search the Internet and obtain relevant information for a certain object on the spot. However, the extraordinary volume of information on the Internet sometimes makes it difficult for users to find the information or service they want immediately. To make it easier to find object-related information on the Internet, Fujitsu Laboratories has developed a technology for embedding ID information in light. Casting of such light on an object and the recovery of the ID from the reflected light using image processing technology enables a user to easily access relevant information by capturing an image of the object with the camera in a smart device. Service providers can use this technology to increase communication channels with end users and expand the services they provide. This paper presents an outline of this technology and explains its usage and potential applications.

1. Introduction

The growing proliferation of smart devices and expansion of the communications environment for accessing the Internet is making it possible to access information just about anywhere at any time. However, the massive amount of information available through the Internet can make it difficult for users to find the exact information they need or services they want. For example, getting details on a product in a store by searching on the product name or model number is troublesome. One way to help users is to connect objects in the real world with network services. This has been done by directly affixing QR codes or RFID tags containing identification information to objects. Today, there is a move underway toward methods that negate the need for affixing something to objects. Such methods use GPS, Bluetooth, ultrasound, or visible light communications to associate information services with physical areas such as buildings, rooms, or corners where objects are located. Although there are a variety of technologies for making smart connections between network services and objects, each is problematic.

For example, directly affixing QR codes or RFID tags to objects is not acceptable when aesthetic appearance is important, such as for products in retail display cases and works in art exhibitions (problem 1). In addition, the use of RFID requires a specialized device for reading identification information, so smart devices lacking such a capability would not be able to make use of that service (problem 2). Furthermore, applying technologies like GPS and Bluetooth to area-based delivery of information to users is not the same as providing information in units of objects such as products or works of art situated right in front of them. Moreover, pinpoint delivery cannot be easily achieved with these technologies (problem 3).

With the aim of solving these three problems, Fujitsu Laboratories has developed a technology for embedding a digital ID (a value associated with product information) in LED light illuminating an object and then recovering the ID for that object.[1] Embedding information that is not visually apparent in the emitted light makes it possible to deliver information about an illuminated object to cameras in smart devices. Additionally, using emitted light enables information to be provided without degrading aesthetic appearance. Furthermore, since cameras that are generally installed in smart devices can receive such information, services based on this technology can be accessed by practically all smart devices on the market. Finally, information can be delivered for specific objects by illuminating them in a pinpoint manner with directional lighting. A user need only aim the camera at the target object to easily obtain that information. This technology can be used to make all sorts of objects such as retail products, works of art, people (personalities), and structures into sources of information.

In this paper, we describe this LED lighting technology, present application examples, and discuss its outlook for the future.

2. Overview

As shown in **Figure 1**, the basic idea is to illuminate an object with light embedded with a digital ID corresponding to that object. A camera in a smart device then captures the light reflected from the object, and an application in the device detects the embedded ID. The application then either provides the user with content corresponding to that ID or connects the user to the service corresponding to that ID. For example, taking a picture of a product displayed inside a retail store can trigger the display of discounts, stock status, and other information related to that product on the screen of the user's smart device.

Investigation of such an application revealed that a user naturally aims the camera not at the light source but at the target object reflecting the light. This means that, from a technical point of view, it is necessary to recover information not from the emitted light but from the reflected light. Furthermore, from an operational point of view, the time and cost incurred for implementing the technology is an important consideration.

The steps involved in using the developed technology are illustrated in **Figure 2**. First, the user aims a smart device's camera at the target object and captures its image. The application in the smart device then detects the light-embedded ID by using image processing. Next, the application sends a query with that ID to a cloud-based system that links the ID to content (information, URL, etc.) and sends that content to the device. In an environment with no Internet access, content items can be stored within the application with their corresponding IDs, and any particular item can be displayed offline if the camera captures an image corresponding to that content's ID.

Since the image processing can be implemented in software, a user need only download an application from an app store to be able to apply this technology and use related services. Moreover, it should be possible to implement most of the directional lighting by leveraging existing lighting facilities such as power supplies. This means that a retail store, art gallery, etc. can implement this technology without adding more facilities like power supplies, thereby enabling early and low-cost introduction. Moreover, as the lighting is highly directional, the range of its illumination can be easily controlled, enabling information to be provided in a pinpoint manner within a narrow range suitable for individual objects.

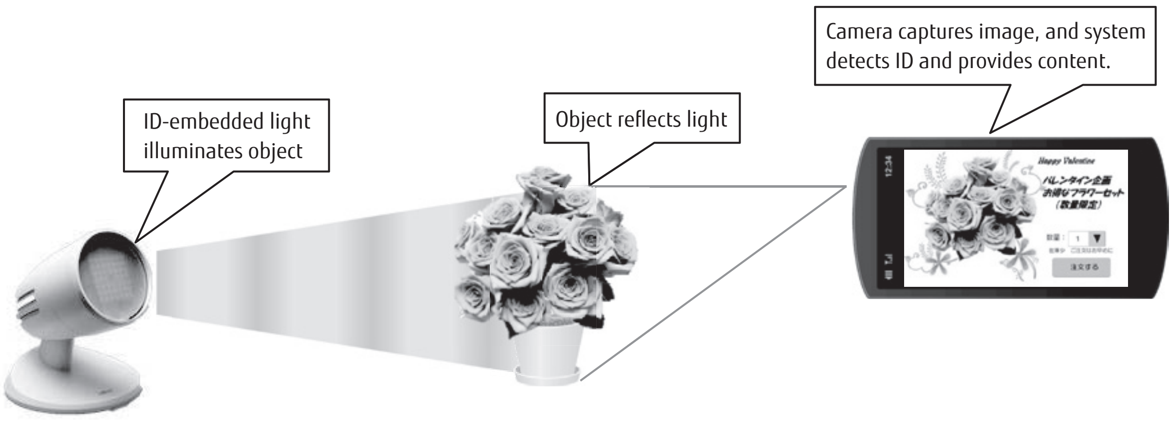

Figure 1
Basic idea of developed technology.

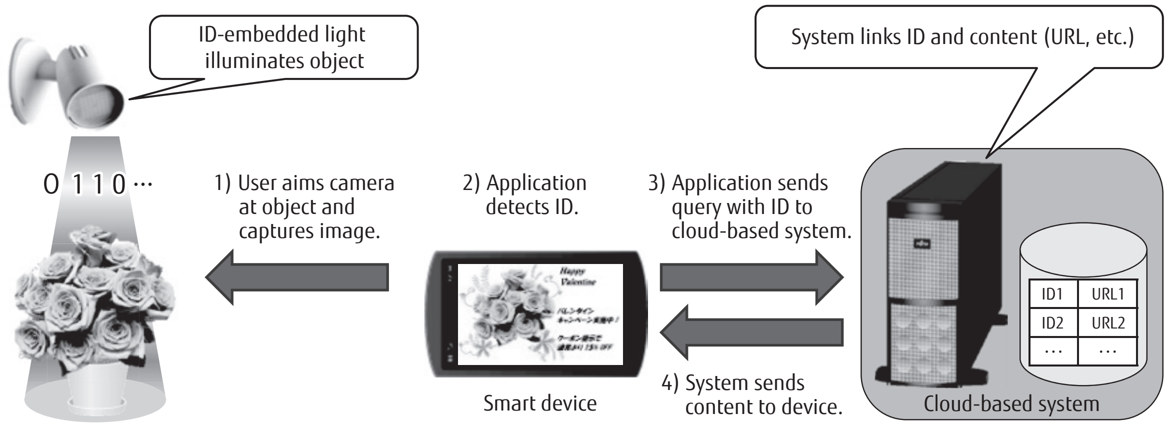

Figure 2
Steps involved in using developed technology.

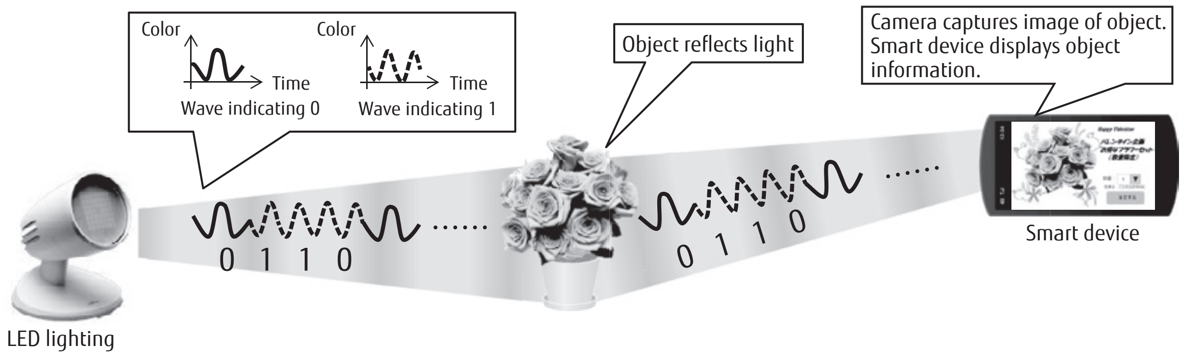

Figure 3
ID embedding by color modulation.

3. Key features

The developed technology has two key features.

1) ID embedding by color modulation

A color LED synthesizes light made up of the three primary colors (RGB), thereby enabling the irradiation of light of various colors. The developed technology embeds an ID by controlling the intensity of the light of each color along the time axis and generating a wave with small variations in the light's color (**Figure 3**). The intensity of each color is adjusted to prevent flicker.

One method for sending and receiving IDs represents them in binary form. As shown in Figure 3, the wave colors are changed along the time axis with one type of wave representing "0" and another type representing "1." An ID composed of binary data can therefore be embedded in light by altering the pattern of these two types of waves. Thus, to send the ID "0110," the system successively emits a "0" wave, two "1" waves, and a "0" wave. The amplitude of these generated waves is extremely small, and any change in amplitude is at a level barely perceptible to the human eye. This means that people perceive the object-illuminating light as ordinary lighting, so it can be used for its original purpose.

Another advantage is that the frequency used for the generated waves is low enough for an ID to be detected and read at the frame rate (30 fps) of ordinary cameras in smart devices, so special receiving equipment is unnecessary. Since the human eye is sensitive to changes in brightness, if brightness were simply varied at low frequency, some flicker could be visible even for slight changes. However, the developed technology uses color changes that are hard for the human eye to perceive, so the flicker is essentially unnoticeable to viewers.

2) Reflection compensation

The developed technology enables detection of IDs not only from the emitted lighting but also from the reflected lighting. However, if the emitted light is reflected off a surface, the colors (wavelengths) of the light are somewhat absorbed depending on the spectral reflectance of the surface. This changes the characteristics of the modulated waves for each RGB element, making it difficult to read the embedded ID. For example, if a blue object is irradiated with white light, the blue light in that light is reflected while the red and green lights are absorbed. The developed technology overcomes this problem by estimating the variation in reflectance of each of the colors in the image captured by the camera and correcting the amplitude of the waves representing the ID in each color component. It also improves ID detection accuracy by restoring as much as possible the wave characteristics of the emitted light to their state before reflection. As shown in **Figure 4**, color compensation by preprocessing is followed by wave extraction. These waves are used to recover the embedded ID.

4. Application examples

The developed technology can be used to provide information not only for retail products and works of art, as described above, but also for large structures like buildings and even living things like people and animals simply by illuminating them with light. Because it enables users to obtain content related to a certain object simply by pointing a smart device at it and taking a picture, it is well suited to various types of services (**Figure 5**).

1) Provision of product information at retail stores
2) Automatic payment and shipping
3) Automatic streaming of explanatory videos at museums and art galleries
4) Explanation of theater program and downloading of music performed
5) Display of explanations of historical sites in visitor’s native language

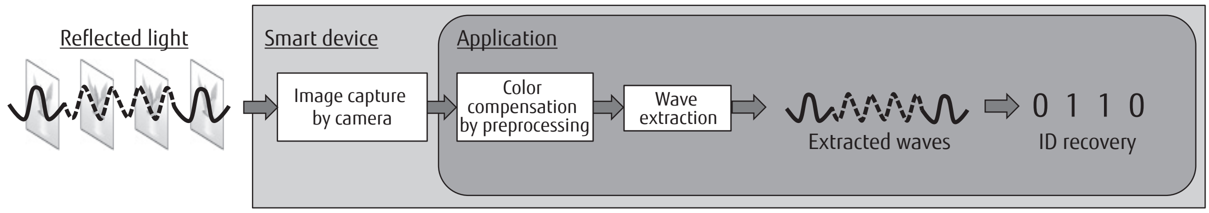

Figure 4
Compensation processing in ID detection.

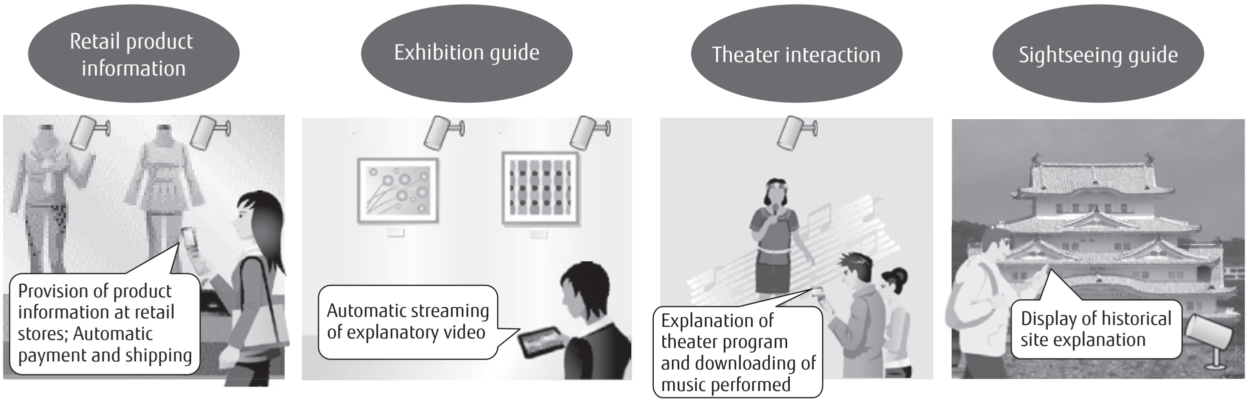

Figure 5
Application examples.

5. Application to projection mapping

Projectors and other types of display equipment generally display images at a refresh rate of 30 Hz or greater while the developed technology sends and receives binary data using waves in which the color of light changes at a low frequency (<30 Hz). Such binary data can therefore be conveyed by images displayed by projectors and similar equipment. Thus, in addition to LED lighting, the developed technology can also be used in an application like projection mapping.

We performed a projection mapping trial using the developed technology at the end of 2014. We embedded an ID in light by varying its color at a level imperceptible to the human eye and projected that light on the wall of a building through projection mapping. Next, we used a dedicated camera application in a commercial smartphone to capture images from a distance of 70 m and 100 m. The ID could be detected in 2 or 3 seconds for pictures taken at either distance.

This trial demonstrated the feasibility of using the developed technology to create new business opportunities such as events incorporating projection mapping and services tied to the lighting of buildings and structures. The trial also enabled us to obtain data essential to the practical application of the developed technology. We plan to hold more trials in a variety of environments and to use the knowledge gained to further enhance the developed technology.

6. Future outlook

In addition to lighting equipment, the developed technology can be used to enable all sorts of existing devices that emit light such as projectors, TVs, and digital signage displays to also serve as sources of information. Since the frequencies used are less than 30 Hz, this technology is applicable to a wide variety of scenarios. However, there are issues related to the lighting that must be addressed. For example, application of the developed technology to outdoor structures requires making it robust to the effects of sunlight, weather, etc. to ensure stable ID detection.

7. Conclusion

This paper explained the basic principle of providing information through lighting technology developed by Fujitsu Laboratories. At present, this technology achieves a transmission speed of 10 bps but studies are underway on embedding 16-bit IDs in objects (enabling the embedding of about 65 000 IDs). Looking to the future, enabling many IDs to be embedded in an object by increasing the amount of embedded information per unit time will make it possible to increase the number of items of content that can be simultaneously provided. This capability could be applied to services that deal in massive amounts of content. At Fujitsu Laboratories, we are also studying plans for holding trials with general users to enable more people to experience this novel technology.

Operators or enterprises that provide services or systems can increase their points of contact with users by introducing this technology. They can thereby obtain diverse types of information for use in providing new services. For example, this technology can indicate what types of users are interested in what types of products or exhibits and which locations with featured objects attract the most user attention. Analyzing this data and feeding customized information back to users can improve the quality of service.

Fujitsu Laboratories has already developed technologies that connect ICT with printed material[2),3)] and with TV and digital signage.[4)–6)] Going forward, we plan to develop technologies that can tie all sorts of objects in the real world to services on the network and to expand the provision of new and compelling services.

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