Optical Wireless Communications Method for Location-based Information Support Using a Corner-reflecting Terminal and a Distance Image Camera

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Abstract: - Optical wireless communications system with a corner-reflecting terminal (CRT) and a distance image camera (DIC) is proposed for location-based information support. By using the CRT and the DIC, the user location can be tracked and detected, and the distance from the camera to the user who is tracked can be obtained real-timely. Therefore, the information support of users can be implemented based only on their physical locations and without the private data such as an address or ID number. We also performed two experiments based on the proposed system and method, and their effectiveness is demonstrated in multi-terminal location detection and indoor data communications.

Key-Words: - Optical wireless communication; Location-based; Corner-reflecting terminal; Distance image camera; Three-dimensional location detection; User information support.

1 Introduction

The method of location-based optical wireless communication is based on the physical location information of the user and by using spatial optical wave as the carrier to do data transmission in an indoor environment. Its attractive features are adequate privacy protection because the data transmissions are based only on the user's location, without the need for a user address, user ID, etc., and information contents safety by the directionality of light beams [1]-[3].

In order to realize the location-based information support, the location information of the terminal and user's messages that are carried by it must be detected simultaneously. In the previous papers [4], [5], we have proposed a method for location detection and message recognition using a general video camera with an infrared LED ring and an infrared bandpass filter. In that method, the video image of the terminal is first captured by the camera, and then, the location information is obtained based on the pattern-matching technique to measure the shape similarity between an idealized representation of a feature and a feature that may be present in the terminal image. However the distance information of users cannot be grasped real-timely.

As an alternative or more efficient method to realize the location-based optical wireless communications, we consider to use a distance image camera (DIC), which can simultaneously take the brightness and the distance of an object to locate users three-dimensionally in this paper. The DIC also can as a light source to transmit information for optical wireless communications because it with a built-in LED array. We have performed two experiments based on the proposed system and method together with the previous proposed video-based optical wireless communication technique [5], and their effectiveness is demonstrated in multi-terminal location detection and indoor information services.

2 Principles of the Method

The main elements in proposed optical wireless communication system are the DIC and the corner-reflecting terminal (CRT). The detail on the structure of the CRT and its data-transmission functions has been described in our previous paper [6], [7]. The DIC will be described in subsection 2.1 as follows.

2.1 Distance Image Camera

Figure 1 is an exterior of the DIC (Matsushita Electric Works E15-04-019), including an infrared LED illuminator that the wavelength is 850nm, a CCD array of 128x123 pixels with a response speed of 15 frames per second, and a control unit.

Fig. 1 The distance image camera (DIC).

The principle for distance measurement by using the DIC is based on the time-of-flight (TOF) technique, as shown in Fig. 2. In this method, we let c is the optical speed, and t is a detected time (or phase) delay between incident light from irradiation LEDs and reflecting light from an object to the CCD array, then the optical path $d = c \cdot t$. And the distance from the object to the DIC is $L = d / 2$.

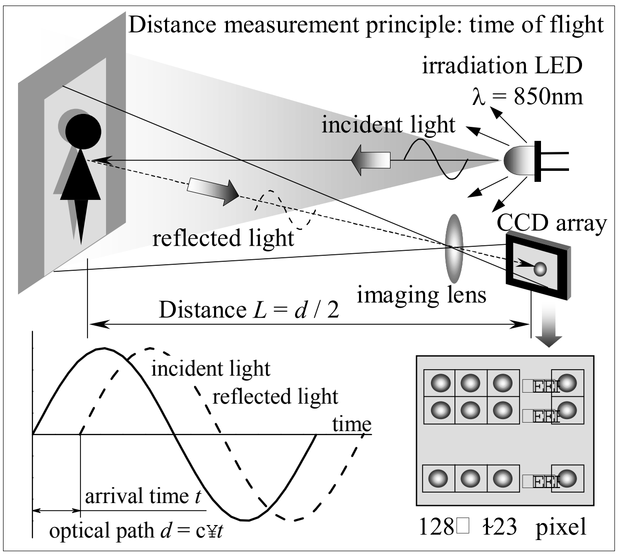

Fig. 2 Schematic structure and measurement principle of the DIC.

Figure 3 is examples of images output and distances detection. Fig. 3(a) is a chiaroscuro image. Three-dimensional coordinates of the point O and its brightness B are detected and displayed, (b) is the distance image which is indicated with color of the (a), and (c) is a rang limitation image of 1.5m.

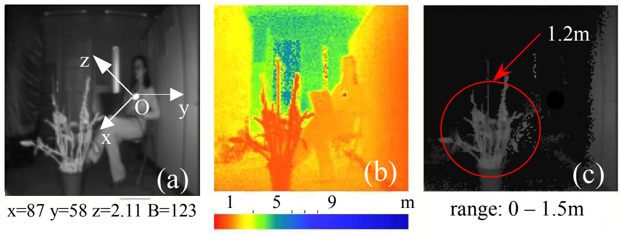

Fig. 3 Examples of image output: (a) chiaroscuro image, (b) distane, and (c) range limitation.

2.2 Location-based Optical Wireless Communications System

Schematic diagram of location-based optical wireless communications method is shown in Fig. 4. It consists of two subsystems. On the environment side, the DIC with the built-in LED array is used to detect the locations of the terminal worn by users, and as a light source to wirelessly and bidirectionally transmit information between the terminal and this environment. A display is used to show messages for users to information services.

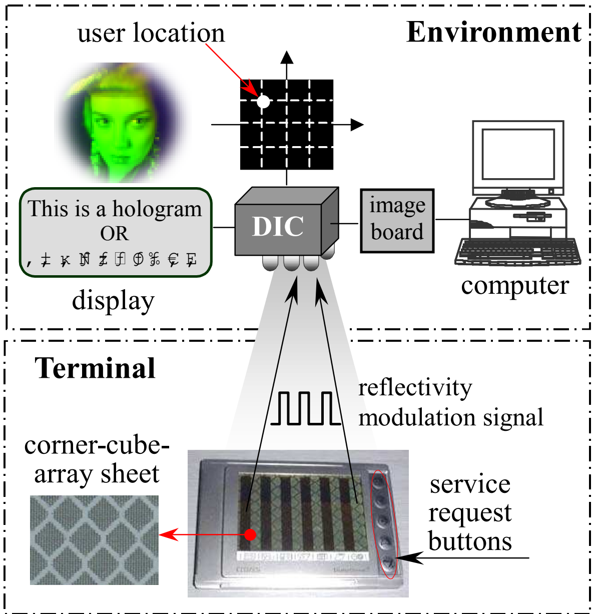

Fig. 4 Schematic diagram of location-based optical wireless communication system with the CRT and the DIC.

On the terminal side, a low-power-consumption and compact PDA (Personal Data Assistant) with a liquid crystal display and equipped with a corner reflector as the CRT is employed to modulate reflectivity to carry data, and upload user information to the environment. For example, there a exhibition in an information environment; on touching different service request button at the terminal panel, users can send the reflectivity modulation signal corresponding to different service request to the DIC. The DIC detects real-timely the location of this terminal and via an image board and a computer to decode the signal sent from terminal, then based on the location information received, show the contents corresponding to user's intention on the display. The data transmission rate of this system will be limited by the frame rate of the DIC and the -3dB bandwidth of the system.

3 Experiments and Results

In order to demonstrate the effectiveness of the proposed method, two experiments are performed to detect the locations of two terminals and realize a basic interactive user information support in an eating house.

3.1 Terminal Location Detection

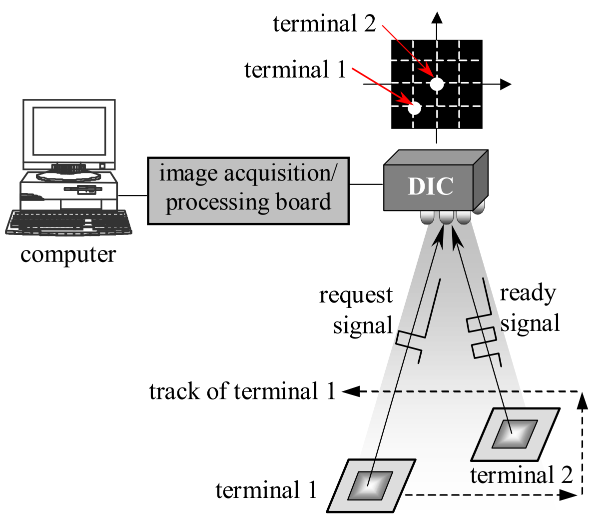

Fig. 5 Location detection of two terminals using the DIC.

The schematic diagram of terminal location detection using the DIC is shown in Fig. 5. The initial locations both two terminals away from the DIC are about 60cm, and then, the terminal 1 is moved around the terminal 2, the nearest and farthest distance away from the DIC are about 50cm and 100cm, respectively. When the area that includes two terminals is illuminated by the built-in LED array of the DIC, the light, which only is from terminals, will be reflected intensively to the DIC, without the background noises because the terminals are corner-reflection devices. The DIC calculates the distances of the terminal at every location based on the TOF technique. The results of distance calculation and location detection are plotted in Fig. 6. The Z-axis denotes the distances from the DIC to the terminals and the X-, Y-axis are plane locations of the terminals.

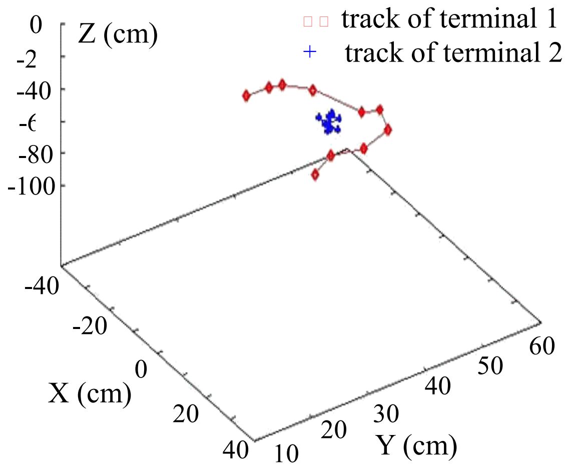

Fig. 6 Three-dimensional location tracks of two terminals

3.2 User Information Support

Figure 7 is an example of experimental results for interactive user information support. The experiment environment is an imaginary eating house, and the communications system is the same as in Fig. 5. There are two users i.e. terminals in this experiment. Their plane move tracks approximate to Fig. 6, and the spatial distance to the DIC is about 2 meter. The code 110 is assumed to indicate a ready signal, and the code 100, 101, and 111 are request signals corresponding to different messages from the user.

Figure 7(a) is reflectivity modulation signals received by the DIC. A request signal of the code 100 from the user1 is found at 102 times, and the location corresponding to this signal sender is also detected at the same time, as shown in Fig. 7(b). And then, the environment side gives an ask message to the user for information service. Finally, the user uploads his selection message to the environment side to get a requisite information service. The communication speed is limited at the 1.5Hz by the reflectivity modulation frequency of the liquid crystal panel of the terminal [6]. Although this communication speed can be used for case of our indoor and near distance, we still want to improve it using a faster device.

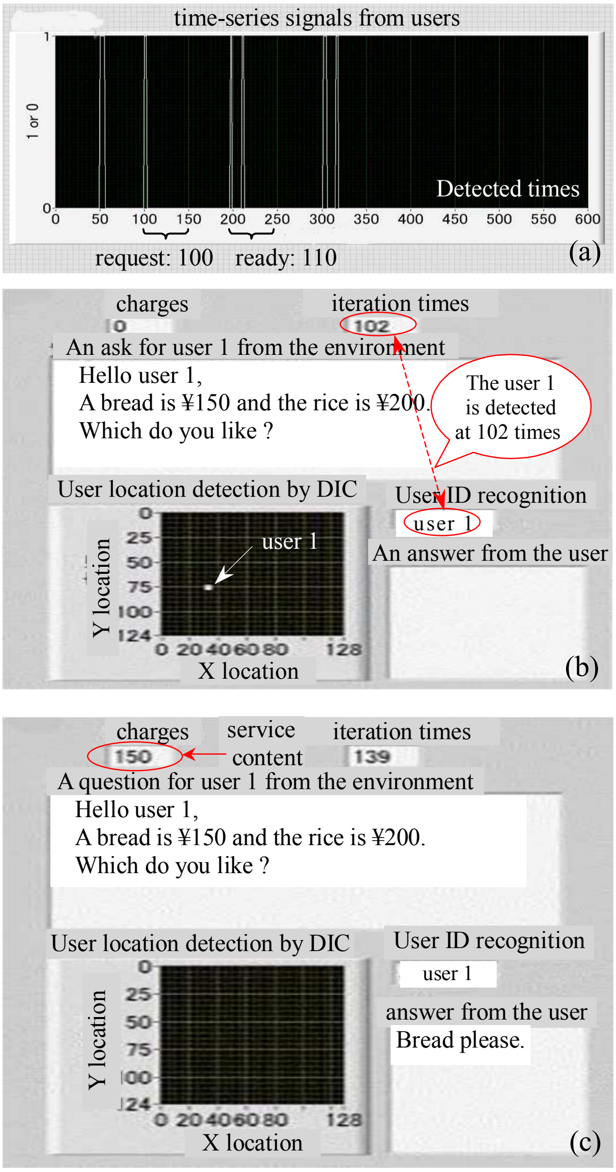

Fig. 7 An example for indoor information service by using the proposed system: (a) detection times of every user code, (b) giving an ask from the environment to information service, (c) uploading the answer from the user and giving a service content from the environment.

4 Conclusion

We have described a method for location-based information support using a CRT and a DIC. In this method, the CRT is used to upload user information and generate intensively reflectional light to extract it from background noises. And the DIC is employed to simultaneously detect the user location and recognize the user information. Two experiments have been performed for location detection and indoor user information support.

References:

[1] H. Nakashima and K. Hashida, "Location-based communication infrastructure for situated human support", *Proc. SCI2001* **IV**, 2001, pp. 47-51.

[2] H. Itoh, T. Nishimura, Y. Yamamoto, and H. Nakashima, "Ferroelectric liquid crystal spatial light modulator for location-based communication with higher data transfer rate," *Tech. Dig. LTA2002*, 2002, pp. 189.

[3] T. Nishimura, H. Itoh, Y. Nakamura, Y. Yamamoto, and H. Nakashima, "A compact battery-less information terminal system for location-based interactive information support," *IPSJ* **44**(11), 2003, pp.2659-2669.

[4] X. Lin and H. Itoh, "Video-based optical wireless communication technique", *WSEAS Trans. on Commun.*, **7**(4), 2005, pp. 417-424.

[5] X. Lin and H. Itoh, "Video-based spatial optical communications method for wearable information terminal," *Opt. Eng.* **45**(6), 2006, pp. 064001-1-064001-6.

[6] X. Lin and H. Itoh, "Wireless personal information terminal for indoor spatial optical communication system using a modified DataSlim2," *Opt. Rev.* **10**(3), 2003, pp. 155-160.

[7] X. Lin and H. Itoh, "Evaluation of Multi-Letters Transmission Quality of a wireless compact terminal for indoor spatial optical communications, " *Proc.(2) of 13th IST Mobile and Wireless Communications Summit 2004*, pp.879-883.