Video-Based Optical Wireless Communications System for a Wearable Information Terminal with Multi-Language Serving

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Abstract: - A video-based optical wireless communications method for wearable information terminal using a video camera with infrared LED ring is proposed. By the image signal of the wearable terminal that is captured by the video camera, the physical location of the terminal and user's messages that are carried by the terminal can be detected simultaneously. Therefore, data communications can be implemented without the private data of users such as address, number, and ID.

Key-Words: - Video-based optical wireless communications; Wearable computing environment; Terminal; Location detection; Information recognition.

1 Introduction

In indoor and wireless local-area network systems, implementation the optical wireless of communications is an attractive issue due to adequate privacy protection by directionality of light beams, human safety because it is electromagnetic wave free, no multipath fading and easily divided into segment because photons are uncharged and do not interfere with one another as readily as electrons. A number of indoor wireless communications systems by infrared radiation have been proposed [1]-[6]. Advantages of spatial optical medium in broadband, high-speed, and high capacity for indoor data transmissions are compared to those of radio and microwave media in these reports. We are investigating a new location-based indoor optical wireless communications system for wearable computing environment. In this communications system, data transmissions only are based on the user's location [7], [8] and time-series change of terminal intensities without user-address, user-ID, etc. which are the private data of users. Our purpose is that to construct a wearable computing environment with privacy and security to support human to obtain necessary information and services in their adequate location. In order to realize such real space, it is important to develop an intellectual information terminal with low power consumption. We have proposed a spatial optical modulation and transmission technique for a compact mobile terminal using a modified PDA (Personal Data

Assistant) and also evaluated the spatial communication quality and data transmission characteristics of terminal equipment using infrared radiation as a medium in our previous papers [9], [10].

As an efficient approach to implement location-based communications in the wearable computing environment, we propose a method for location detection and information recognition of terminal equipment using camera with LEDs based on the video signals analysis in this paper. A video-based spatial optical communications system is constructed firstly, and then a pattern-matching algorithm based on the optical pattern recognition technique is applied to find, track, and detect the location information of the terminal, and a method for user (or terminal) information recognition by using the time-series signals of intensity modulation of terminal image is described. Finally, an experiment for multi-language selection indoor communications an information in environment using proposed method is performed, and experimental results indicate that the proposed video-based spatial optical communications method effective is in short-range location-based communications system.

2 Video-based Optical Wireless Communications System

The video-based spatial optical communications

system for wearable computing environment as shown in Fig. 1. It consists of three subsystems. At the wearable environment side, one (or more) wireless camera with an LED ring and an infrared bandpass filter is used to find and track terminal equipments that are worn by users, and wirelessly transmit the video image data between users and this information environment. A major problem in an indoor wireless communications system is how to select radiation source, that is, medium of information transmission to guarantee safety of human eye. We have chosen the near infrared LED ring which the light-emitting wavelength is 870nm. Each LED in the ring has wider half-angular breadth of about 15deg and half-power width of about 60nm Additional, LED is incoherent source make its image dispersive in the retina. So this LED ring is safe for eye [11].



Fig. 1 The video-based optical wireless communications system.

At the terminal side, a low power consumption and compact PDA (Personal Data Assistant) with a liquid crystal display and a corner-reflection is employed to encode visual information mark, modulating the reflectivity to carry data, and wirelessly upload information of users. In order to make the PDA a corner-reflecting device, we remove its original light-scattering-reflection sheet, and then embed a corner-reflection sheet behind its liquid crystal panel as shown in Fig. 2. The buttons at right of the PDA panel are used to control and select the communication messages, which are desired by users. The corner-reflection sheet is a combination of many corner cube arrays, and each array being an injection molded plastic plate of small corner cube prisms. Each corner cube prism has three mutually

perpendicular surfaces and a hypotenuse face. Light entering through the hypotenuse is reflected by each of the three surfaces in turn and will emerge through the hypotenuse face parallel to the entering beam. The prism thus returns the entering beam to its source. As a reflection type terminal equipment, not only is the capability of corner-reflection require, but also the capability to modulate the reflectivity for data transmission. To realize the capability of reflectivity modulation, we have developed some application software for this PDA to encode visual information mark, modulate the reflectivity of the PDA by the messages/ID from users, and so on [9].





Fig. 2 The terminal equipment.

We have chosen an image acquisition board IMAQ PCI-1409 which has good image processing and pattern recognition capability to decode the information mark that display in the terminal equipment or detect the time-series change of brightness and realize shiftterminal and rotation-invariant terminal pattern recognition at the processing side. However, this image board cannot implement a scale-invariant pattern because its Vision tools are using the pattern-matching principle to find and detect an image. We are considering and using a method of spatial mapping in biology vision field. This method can transform an input image becomes a scale-invariant pattern by the coordinate transformation that is called the complex-logarithm mapping [12], [13].

There are two subjects is important to communicate between users and the wearable information environment in this video-based spatial optical communications system. One is "Now, where are you?" and other is "Now, what do you want to do?" To give an answer for the first question, a method for the user, or the terminal location detection is proposed and described in Section 3. And to answer the second question, a technique for terminal information recognition is investigated and described in Section 4.

3 Terminal Location Detection

There are two-dimensional feature data, which are the shape and brightness, can be used to help find, track, and detect the location information of the terminal in proposed video-based spatial optical communications system. We have developed a pattern-matching algorithm based on the optical pattern recognition technique to measure the shape similarity between an idealized representation of a feature, called a reference image or a template image, and a feature that may be present in a terminal image by the *IMAQ Vision tools*. Using this algorithm, pattern matching can find template matches regardless of poor lighting, blur, noise, shifting of the terminal object, or rotation of the terminal object.

On the other hand, because the terminal is a corner-reflection device, when it is illuminated by the light source of the communications system, the signal light that is carried by the terminal will be reflected intensively to its source, thus, making it easy to extract terminal pattern from background noises. The brightness values of the terminal also can be obtained by proposed pattern-matching algorithm simultaneously. Additional, the video camera has a bandpass filter in its entrance window, which is adapted for the light-emitting wavelength of the light source. Hence, the effect of noises from the environment illumination can be obviated.



Fig. 3 An example of program implementing for terminal location detection.



(a)

(b) Fig. 4 Results for the terminal location detection: (a) shift-invariant and (b) rotation-invariant.

investigate location detection To the effectiveness of the terminal, we implemented an experiment using proposed video-based spatial optical communications system and location detection method based on the pattern-matching algorithm. Figure 3 is an example of program implementing for this experiment. The image at the upper left of Fig.4 is a template, and it has good symmetry, feature detail, and positional information to obtain an exact pattern matching result. The test terminal is placed in an environment that has noise and blur, and the distance to the video camera is about 1.2 meter as shown in the upper middle of Fig.3. Numerical values at the upper right of Fig.3 are terminal brightness and the terminal position coordinates, which are obtained from its shape feature and brightness information. By these transient positions of the terminal, the terminal track on the user move plane XY can be obtained as shown in the lower left of Fig. 3. The X-axis and Y-axis denote the positions of a user with the terminal in the wearable computing environment, respectively. This result can help us to know the move history of a user in its walk range. The sequence before and after that the users with the terminal are appeared in the field vision known of also can be from the three-dimensional plot at the lower right of Fig. 3. The Z-axis is the move sequence of the terminal. Thus using two-dimensional feature data of the shape

and the reflection intensity, high location detection effect can be realized. By this experiment, some results for the terminal location detection and capture are obtained as shown in Fig 4. The light rectangles are captured terminal patterns, and the light specks are background noises in the field of vision of the video camera. The shift- and rotation-invariant terminal detection are shown in Fig. 4(a) and 4(b), respectively. These results also indicate that the proposed detection method is effective for finding and capturing an image within noises.

Figure 5 is other results of the terminal location detection when the distance from the terminal to the video camera is about 3 meter. In this case of the longer distance, although the terminal shape recognition becomes difficult, but because the corner-reflection effect of the terminal equipment, good location detection results also can be obtained as shown in Fig 5 (a) for single terminal and Fig 5 (b) for multi-terminals, respectively. However, the detection capability has a little down due to only has one-dimensional feature of the reflection intensity is used to terminal location detection.



Fig. 5 Terminal location detection for longer work distance: (a) single terminal and (b) multi-terminals.

4 Terminal Information Recognition

At the same time for the terminal location is detected, if the function control buttons at the terminal panel are pressed, the reflectivity of the liquid crystal panel of the terminal will be modulated by the signal codes, and they correspond to the messages, which are desired by users. How does the proposed video-based spatial optical communications system recognize these image data from the terminal? Two methods are proposed to solve this problem correspond to shorter and longer communication distances respectively, and they are described as follows.

4.1 Method of Information Recognition for Shorter Communications Distance

In the case of shorter communications distance, to quick transmit data between the terminal and the information environment, we have developed an application software to encode and display various visual information marks immediately at the liquid crystal panel of the terminal by using programmable function of the PDA. In this method, the liquid crystal panel of the terminal (PDA) is divided by bright (code "1") and dark (code "0") visual marks becomes four sub-blocks as shown in Fig. 6. Each sub-block corresponds to a code of 1 bit. The four sub-blocks combined to make a code of 4 bits, which can correspond to various messages. For example, we use code "1101" to denote English contents, "1110" to denote Japanese contents, and so no. These visual information marks are taken by the video camera, and then, converting they become recognizable binary codes by the proposed program to support the users to get the interactive information that has an interest for them.



Fig. 6 The terminal with visual information mark.

Figure 7 is an example of visual information marks corresponding to user's messages by running the proposed control program. An image for selection of contents which are desired by the user will be popped. Guided by this image, *e.g.*, there is a picture in an exhibition hall, if the user wants to get an English explanation about this picture, by touching the first button at right of the PDA panel, a visual information mark corresponds to the English contents will be displayed in the screen of the PDA.



Fig. 7 Terminal information recognition by the image encoding technique.



Fig. 8 An example of program implementing for terminal information recognition using the time-series image signals.

In this moment, this image is captured by the video camera, and then, it is transmitted to the image acquisition board IMAQ for threshold processing and becomes a binary image that is corresponded to the binary code "1101". Decoding this binary code, the English contents can be obtained. Similarly, if the user wants to get a Japanese explanation about this picture, only by touching the second button, the terminal will be displayed another visual information mark that corresponding to the code "1110", and giving the Japanese explanation to user.

4.2 Method of Information Recognition for Longer Communications Distance

When the distance from the terminal to the video camera become long, using visual marks to transmit information is difficult because the clearness of the visual mark decreases with increasing the



Fig. 9 Time-series signals of terminal image intensities correspond to the different information codes: (a) 00101100, (b) 00101101, (c) 00101110 and (d) 00101011. Superordinate 4 bit and subordinate 4 bit are start code and data code, respectively.



time-series signal for image modulation (start code "0010"+data code "1110")

Fig. 10 An application for multi-contents serving in an indoor information environment.

communication distance. For this case, we proposed another method that is using the time-series change of the reflection intensity of the terminal to realize recognitions and communications of the terminal information. In this method, the reflectivity of the terminal (the PDA) will be modulated by time-series bright (code "1") and dark (code "0") images, which are corresponding to the necessary information and services in users. All these bright or dark images of time-series change are taken continuously by the video camera, and then, transmitted to the image acquisition board IMAQ for converting them to the binary codes. Decoding these codes data using a control program, the contents for user information support can be obtained.

An experiment has been implemented to investigate and evaluate the effectiveness of proposed method of the terminal information recognition. Figure 8 is an example of program implementing for this experiment of the terminal information recognition. The image at the upper left of Fig. 8 is a test terminal, and the black square in its center is a region of interest for reflection intensity detection. The distance from the terminal to the video camera is about 3 meter. The frame at the upper right of Fig. 8 is a time-series change signal of the reflectivity modulation that is formed by RZ (return to zero) type. The data stream consists of a 4 bit star code (0010) and a 4 bit data code. The white line is threshold level for converting this grey-level signal to a binary signal. The frame at the lower right of Fig. 8 is the binary signal after threshold. There are four time-series modulation signals are used to this experiment for three-language serving (1100: Chinese, 1101: English, and 1110: Japanese) and one service-contents index (1011). Their received signals are shown in Fig. 9. The frequency of the video image transmission is 1.28 Hz.

Figure 10 is an example of experimental result. A start image will be displayed in the terminal when running this program, and then, if the "Start" key is touched, another image for the service-contents index will be popped. Guided by this image, using operations are the same as Fig. 7, users can get interesting information such as multi-language service, interactive talk, and so on. On the other hand, if the "End" key shown in Fig. 6(a) is touched, this program will end and await the next command from the user.

5 Conclusion

We have constructed a video-based optical wireless communications system for wearable computing environment. Several methods have proposed for terminal location detection based on the optical processing technique and terminal information recognition based on the video signal detection technique. By using proposed communication system and detection methods, the experiments for multi-language service are implemented in an indoor information environment.

The target of this study is to construct a ubiquitous computing environment with flexible multimedia information support and to develop a compact, smart, secure, and low-power-consumption information terminal that working in constructed communication environment. So further study for wireless indoor data communications via free space beam should be conducted. References:

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