Kinect Positioning System (KPS) and its potential applications

Kinect-founded Advanced Indoor Positioning System

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***Abstract*— This paper outlines the mechanism and the potential applications of KPS. KPS, named after Kinect Positioning System, is an epoch-making system that makes it possible to develop new approaches to educational technology for teacher training, special support education, sports coaching, etc.**

Most of the existing indoor positioning systems are not feasible in that they do not achieve enough accuracy in position detection despite their required large scale devices. Some systems are proposed, in which the position is detected by taking pictures of the target person with a video camera and recognizing the face or the position of slippers is detected by the floor covered with a large amount of RFID tags. However, they have many problems. For example, taking face pictures may cause some privacy issues, or the large scale special devices require considerable cost and preparation. Those difficulties are hard to solve.

In 2009, the authors developed WPS, a highly accurate indoor positioning system that uses Wiimote a controller of game machine Wii. WPS, which only needs low-cost equipment and easy settings, can detect indoor positions more accurately. It is, the authors believe, the best indoor position detection system to deal with privacy issue.

WPS is utilizing a device of tracking infrared rays, which requires the installation of an infrared photophore on the shoulder of the target. We solved the difficulties by developing the advanced indoor positioning system, KPS. KPS can detect the indoor position of the target using Kinect without an infrared photophore. Kinect can detect the target using its skeleton. Therefore, it is not necessary to install any device on the target. In addition, KPS can cover a wider range of WPS using one Wiimote. That realizes easier settings freed from constraints of WPS.

Keywords- KPS, Kinect, easy settings, high accuracy, low cost

I. PROLOGUE

Global Positioning System (GPS) helps to develop OUTDOOR position detecting systems, which are so simple and accurate that their possible applications are very various. However, it is not as easy to realize similar INDOOR position detecting system. Some systems are proposed, in which, for example, the position is detected by taking pictures of the target person with a video camera and recognizing the face [1], or in which the position of slippers is detected by all over the floor arranging the RFID tags [2], etc. However, they have a lot of problems. For example, photographing faces may cause some privacy issues, or the large scale special devices require heavy investment of money and time for preparation. Developing indoor position detecting systems tends to bear many more such problems than their outdoor counterparts. WPS, which the authors developed before is one of the few indoor position detecting systems which were intended to avoid as many such problems as possible. It only requires a certain inexpensive equipment, easy setting and simple operation. In addition, WPS is an effective indoor position detection system in dealing with privacy issue. [3]

However, WPS still has some points which should be improved, and it is hard to improve those points as long as the system is founded on Wiimote. The authors eventually decided to develop Kinect Positioning System (KPS) which winds up as a far more efficient position detecting system with higher usability.

II. Development on Wiimote Positioning System (WPS)

A. Hardware Components

The authors first planned to develop the indoor positioning system which would achieve low cost and easy use. Wiimote, the remote controller of the Nintendo game machine Wii was the best choice as the basic machinery for our planned indoor positioning system. It has the acceleration sensor, the infrared camera, and the Bluetooth telecommunication function, etc. [4] Even though it is equipped with all these functions, it can be bought for only about $40. Our developed indoor positioning system, which is named Wiimote Positioning System (WPS), requires PC with the Bluetooth telecommunication function to communicate with Wiimote and the infrared rays photophore installed on the pursuit target person. However, they are all the hardware that it needs besides Wiimote.

B. Gist of WPS

The infrared rays photophore is installed on the target person who should be pursued, and it is tracked by the infrared camera on Wiimote. WPS records the position and time of the target captured in the Wiimote infrared camera and maps the actual location by a comparison with the previous calibration data.

C. WPS Record/Playback Program

Figure 1 represents a window of the WPS application program. The left display region shows the measurement image by Wiimote, and the right one displays the map in the expected area. This screen also shows various information from Wiimote, such as the offset, the calibration, the battery power, etc. This instantiates measurement by only one Wiimote.

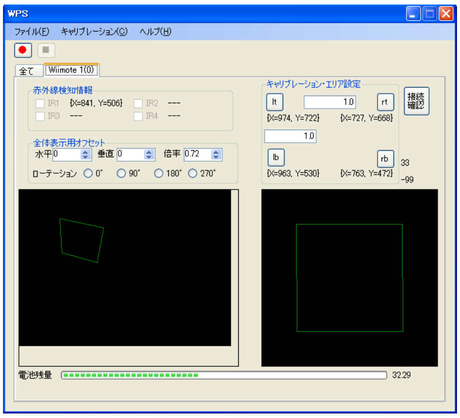

Figure 1 Screenshot of WPS

D. Problems

For all of its advantages, WPS still could not solve the following problems.

- An infrared-photophore has to be installed on the target person's shoulder.
- Two or more targets cannot be handled in WPS.

III. Development on Kinect Positioning System (KPS)

A. The necessity for KPS development

While keeping the inexpensive and easy-to-use spirit of WPS, the authors went on to the development of a new indoor positioning system that could trace more than one target simultaneously and yet would not require any equipment to be installed on the target(s). It utilizes Microsoft Kinect instead of Wiimote, and it is christened Kinect Positioning System (KPS).

B. Gist of KPS

First, KPS identifies the background (what does not move) for detecting a moving object. Figure 2 shows the depth picture for one frame which entered from Kinect.

Figure 2 Detecting Background

KPS extracts such 100 frame pictures at random out of stream data, and calculates the average of each pixel.

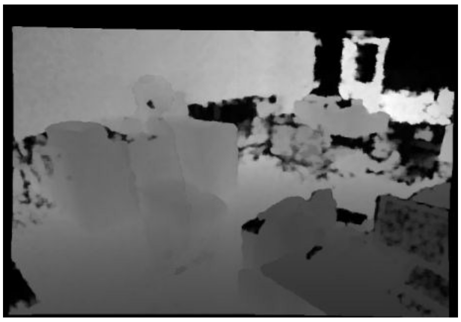

Figure 3 Result of Average Calculation

The shadow looks like a blurred figure as in Figure 3 because instantaneous depth information remains as weight. Since the average values are updated, whenever there is no moving object in the same place, the shadow melts into the background gradually as in FIGURE 4.

FIGURE 4 BRIGHTNESS AMPLITUDE

Furthermore, KPS calculates brightness amplitude. KPS detects rocking in a background and takes it as the threshold value which distinguishes the width of rocking from a background. The moving object extracted from the result of FIGURE 4 will be like the white figure in Figure 5.

Figure 5 Detecting Moving Object

KPS will identify the figure as part of the background if the depth information of the background resembles that of the figure. Moreover, it may mistakenly recognize some portion of the background as a moving object if any rocking is detectible in that portion. There can be holes in the portion considered to be a figure, or some vague trembles can be mistakenly identified as moving objects. Since KPS will display any moving entity in clear-cut white if the motion is obvious, it is necessary to remove the other portion that does not correspond to the entity. There are some methods of noise reduction. When there are a lot of large noises, KPS performs mosaic processing, first of all, to remove the noises except the portion which turns into clear-cut while in designated block (5x5 pixels). It takes long time to perform the relevant process for analyzing the whole picture of every 25-pixel block each time; therefore a picture is reduced and the shade of the pixel was displayed. If the portion which is not the perfect white area in Figure 5 is removed, the figure appears as in Figure 6.

Figure 6 Removing Noises

In order to remove a small noise, KPS performs the contraction and expansion processing of a pixel area. Thereby, 1-pixel noises disappear. Furthermore, expansion is applied in order to ease the unevenness under white set. (Figure 7)

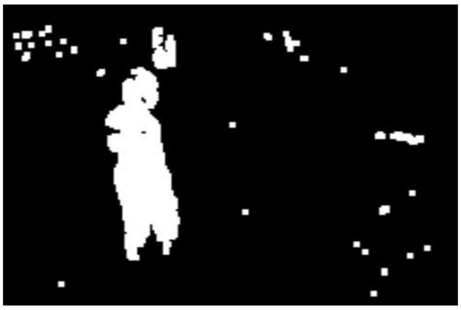

Figure 7 Contraction and Expansion

The outline of each pixel set is detected and the area smaller than the specification value is removed from the result of Figure 7. Only a big white lump remains more often than not. (Figure 8) If Figure 8 is used as a mask and the original depth information is extracted, it will look like what is shown in Figure 9.

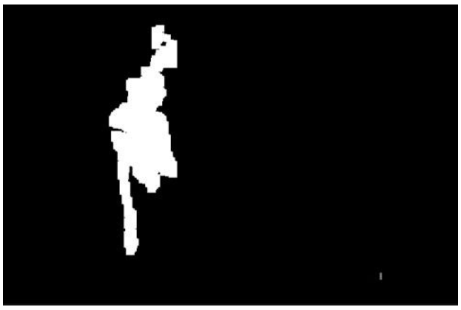

Figure 8 Big White Lump

Figure 9 Masked Depth Information

Since the moving object has been expanded at the time of noise reduction, the extracted depth information is somewhat larger than the actual moving object. This is intended to alleviate undesirable effects of the background renewal. If the information fit in the actual moving object exactly, some outline portion of the object would be mistakenly used as a renewal value of the background, and garbage could interfere with the background recognition. The amplitude value of the extraction can serve to remove the garbage beforehand.

Out of this extracted moving object picture (the portion other than black), the area whose difference with a contiguity pixel is large is detected, and it is used as target outline. The small black dot is intelligibly added to detection coordinates in Figure 10. It is unnecessary in actual, so it is not putting in.

Figure 10 Target Outline

KPS compares the discrepancy in this outline between an earlier frame and a present frame, and KPS gives relevant information, if pursuit is possible. The red lines, which connect the related points in Figure 11, are computed as the movement. Although some lines are prolonged in the mistaken direction, this is removable by specification of a threshold value (the maximum movement). In the next step, individual pursuit can be performed, because KPS detects and labels each moving object. Although the color recognition for clothes might seem easy to apply to individuals, it can be hindered by several factors. The figure will be hard to detect if it wears clothes of different contrastive colors. Moreover, the color recognition will be much harder in the dark.

Figure 11 Target Detection

The standard library of Open NI cannot recognize targets at a distance longer than 4m and cannot track more than one target. In contrast, KPS can track two or more targets by tagging them respectively, covering a depth of about 10m.

The infrared camera has an optical resolution of 320 x 240, which applies to moving images as well as still images. Besides the RGB camera serves to track more than one moving objects by distinguishing them with respect to their color. Therefore, KPS does not need such calibration as WPS requires. This calibration-free feature allows KPS to continue the position detection of the targets in a couple of seconds, even if Kinect is slightly moved during measurement. Once the targets go out from the camera coverage, KPS starts their detection anew.

C. *KPS Application Program*

KPS performs the target position detection through the process described above. Figure 12 shows one of the KPS applications. Users can move a camera position by mouse operation, and a background image can also be superimposed on this. Moreover, a position can also be mapped on a two-dimensional plane comparable to that of WPS in Figure 1. It goes without say that KPS identifies two or more targets and carry out their move pursuit.

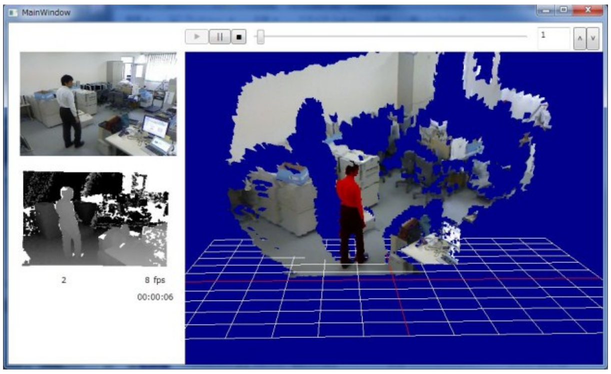

Figure 12 KPS Application Program

IV. EPILOGUE

The authors have managed to realize Kinect Positioning System (KPS), which requires only PC and Kinect as hardware. It can detect 10 meters depth and more than one target with no extra hardware to be installed in contrast with WPS. It has considerably high efficiency, but the setup is simple and the equipment is very cheap. These features are great advantages with respect to which KPS surpasses any other indoor positioning systems including our former WPS.

The authors are now entertaining a wide range of applications such as teacher education, special support education, baby-sitting, nursing care for elderly people, etc. KPS is, we hope, a very useful and promising system in that it is expected to serve for such diverse situations in addition to its advantages of solving the problems that have hobbled other indoor positioning systems. It will open and provide large research domains that await new approaches to the various fields of educational technology.

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