IEIE Transactions on Smart Processing and Computing

Infrared LED-Based Arcade Gun System for Wide Screen

YoSeph Choi[1], DuCheol Kang[2], and TaeSoo Yun[3]

[1] Division of Visual Contents, Graduate School of Dongseo University / Busan, South Korea Seb.knights@gmail.com
[2] Arcade Game Regional Innovation Center, Dongseo University / Busan, South Korea
kdc8865@gmail.commailto:dwkim@cs.utah.edu
[3] Division of Digital Contents, Dongseo University / Busan, South Korea yntaesoo@gmail.com

***** Corresponding Author: TaeSoo Yun

Received January 15, 2014; Revised March 17, 2014; Accepted July 28, 2014; Published October 31, 2014

** Short Paper*

** Extended from a Conference: Preliminary results of this paper were presented at the ISCE2014. This present paper has been accepted by the editorial board through the regular reviewing process that confirms the original contribution.*

Abstract**:** The arcade gun has been a popular game controller in the video game market from the 1970s. The arcade gun, which is used partially in game centers and domestic games, recently is utilized as the interface for the interactive system and tangible media. On the other hand, the existing arcade gun has limits on hardware so it is unsuitable for wide screens. In addition, being platform-dependent, it is inapplicable to various types of content as a single module. This study suggests a correction algorithm that establishes an arcade gun system based on an infrared camera to solve those drawbacks and apply to possibly numerous surroundings.

Keywords**:** Infrared LED, Arcade gun, Game interface, Interactive, Vision camera

1. Introduction

The arcade gun is a controller offering an interface similar to the actual experience of shooting game content with a ballistics model applied in the game centers and the domestic games.

The existing arcade guns are classified as light guns and positioning guns, depending on the display type of hardware. The light gun is a way to use the scanning line and vision camera of the display device. The process of operation is to output a certain pattern from the light gun to the display device and recognize the printed pattern by the optics device attached to the light gun.

The pattern depends on the scanning method and the renewal speed of the display device. Therefore, it is unavailable for the progressive scanning method, such as LCD or beam projector but only for the CRT devices in the interlacing method. The positioning gun has a fixed axis to the aiming direction from the value of the analog potentiometer. Because its position is fixed at the axis, it is less realistic. Moreover, to arrange the position of the axis according to the type of content, it needs to be adjusted as the content changes. Therefore, it is used more on a single platform device at a game center, rather than for general use on various contents [1-7].

In the case of the light gun, which is used for simplicity of operation and the convenience of setting, the demand for replacement with a new approach is increasing as the LCD TVs becomes popular and wide screens with a technical barrier to the CRT device spreads. In this context, the corporation, Nintendo, introduced a new controller with an infrared LED in the Game Show of Tokyo at the end of 2005. This device, known as Wiimote, has a sensor bar at the middle of the upper part of the display device and recognizes the position with the optical sensor of Wiiremote. In terms of the optical sensor, the independent module, its data structure was distributed by hackers and has been applied in many areas [3]. This study suggests an algorithm for correcting the point of impact and establishing the arcade gun system using Wiimote optical sensor based on an infrared LED for the purpose of the convenience of setting and the diversity of application in new circumstances with a wide screen using a beam projector.

2. System Composition

The system consists of an infrared output module,

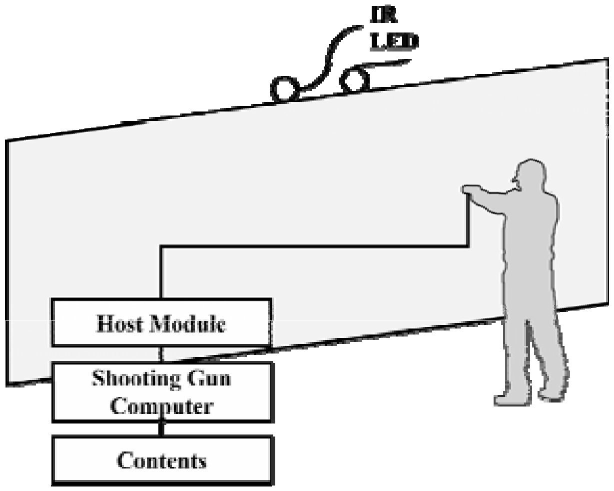

Fig. 1. Shooting Gun System.

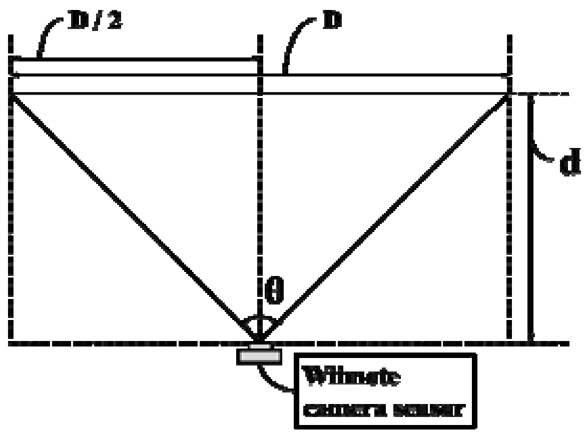

Fig. 2. Camera sensor FOV.

shooting gun module, and correction module. To simplify the system, the infrared output module uses just two infrared LEDs. The infrared LED, set horizontally at the middle of the upper part of the screen, is used as a reference to calculate the origin of coordinates of camera and the rotation angle of the shooting gun. Shooting gun module transmits the coordinates of infrared rays printed out from the Wiimote optical sensor to the correction module after combining with the serial number for the shooting gun distinction and the data for whether it has been shot. The correction module then adjusts the inputted coordinates to content and prints out [Fig. 1].

3. Infrared Output Module

The infrared output module consists of two infrared LEDs, set horizontally at the middle of the upper part of the screen. The infrared LED shows two types of data, which are required to correct the coordinates.

The first is the slope of a straight line for a rotation correction. A straight line is represented by two dots. Therefore, each infrared LED is recognized as dots and is converted to the data of straight lines. Those recognized straight lines are used to obtain the slope and then are referenced in the rotation correction.

The second is the distance from the screen to the Wiimote optical sensor. The straight distance between two infrared LEDs changes by the relative distance with the Wiimote optical sensor [Fig. 1].

4. Shooting Gun Module

The shooting gun module has a part of wide-angle lens for recognizing the wide-screen and the other part of transmission for sending the coordinate data from the Wiimote optical sensor to the correction module.

To create the coordinates from the Wiimote optical sensor, the infrared LED must be recognized. Therefore, a wider angle of view is needed to recognize the entire range of a wide screen. The recognition range of a camera sensor (Fig. 2, D) by the distance (Fig. 2, d) and the FOV (Fig. 2, θ) is computed using [Formula 1] and [Formula 2] [4].

Table 1. Wiimote Camera Sensor Specifications.

Wiimote Camera Sensor	
Manufacturer	Pixart
FOV	45°
Pixel clock	24MHz
Camera type	Monochrome camera
IR blob detection	max : 4 Points
Built-in image processing	128 x 96
Sub-pixel analysis	1024 x 768
Point range	x : 0 – 1023
	y : 0 - 767

$$\frac{\boldsymbol{D}/2}{\boldsymbol{d}} = \tan\left(\frac{\theta}{2}\right) \tag{1}$$

$$\boldsymbol{D} = 2 \cdot \boldsymbol{d} \cdot \tan\left(\frac{\theta}{2}\right) \tag{2}$$

The perceptible screen range is two times wider than that of the camera based on the infrared output module [Fig. 3]. For example, the Wiimote optical sensor with a viewing angle of 45° can recognize a five meter-size when the distance between the screen and Wiimote optical sensor is three meters. As human sight has an approximately 70° angle of view, if the angle of view increases to 100° by attaching an optical lens to Wiimote optical sensor, it can use an almost fourteen meter-sized screen.

Depending on the content, it is possible for multiple users to operate simultaneously. Therefore, a serial number for distinguishing each shooting gun used by separate users is necessary. The serial numbers are given when sending from the transmission part of the shooting gun module to the correction module [1, 2].

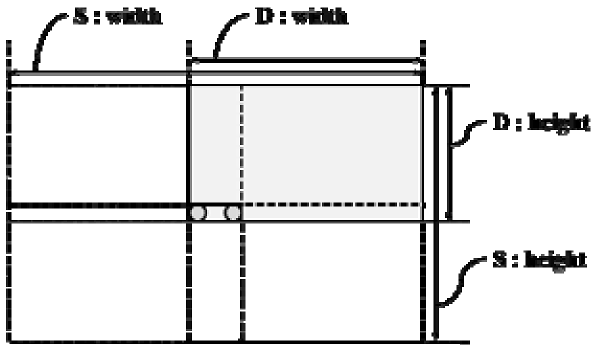

Fig. 3. Screen size.

5. Correction Module

The correction module consists of two programs; 1) a program of coordinate correction and 2) a program for coordinate transmission. The coordinate correction is processed by the following four steps: the coordinate system, the origin of coordinates, moving in points, and the rotation correction. The data coordinated with the final correction is transmitted to the system of content. As a connectionless process in real time, the coordinate data communicates using the UDP broadcasting method.

6. Coordinate System

In the system, there are three types of coordinate systems, screen, camera and content. The coordinates of the infrared LED from the screen coordinate system are eventually converted to the content coordinate system through the correction algorithm.

The screen coordinate system shows the actual size of the screen and is used as the aiming coordinate. To simplify the process of converting coordinates, it is made similar to the content coordinate system. Generally, the top left-hand corner of the screen is the origin [Fig. 4].

Fig. 4. Screen Coordinate.

The camera coordinate system follows the specification of the Wiimote optical sensor. The top left-hand corner is the origin and its size is a maximum of 1024 x 768 (width × height). After the process of binary-coding, removal of noise, labeling, extracting the mean point of the range and tracking, the infrared LED recognized by the camera outputs four x and y values as the maximum [Fig. 5].

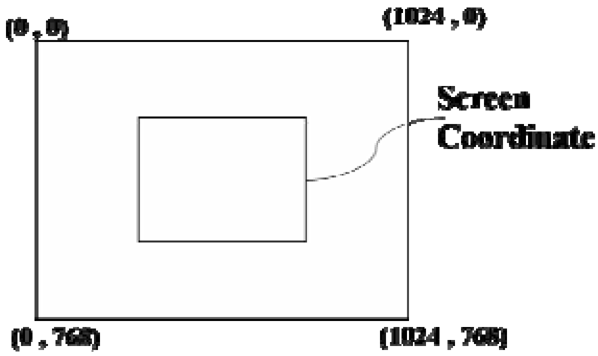

Fig. 5. Camera Coordinate.

The coordinates from the camera coordinate system are converted to the coordinates of the impact point in the content coordinate system. This can be applied to various contents [Fig. 6].

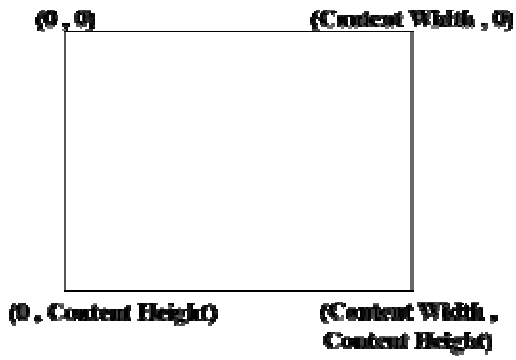

Fig. 6. Content Coordinate.

7. Correction Algorithm

In the process of converting to the impact point, several errors in the aiming point are possible: 1) the error in the origin and moving aiming point between the screen coordinate and camera coordinate, 2) the rotation error by tilt in the right and left side of the shooting gun, and 3) the error in the lens by the optical lens of the camera module. Each error is corrected in three steps, according to the flow chart in [Fig. 7].

In general, the correction of error by an optical lens is processed in the camera module. This system selectively corrects each type of error in content module. In the case of optical lens, there is too much correction to be computed and its error usually occurs at the edge of the screen. As the advantage of a real time process and the needs for accuracy at the edge, the correction procedure of an optical lens is carried out selectively in content module.

Each step in the correction refers to the value of a straight distance between the two infrared LEDs, the

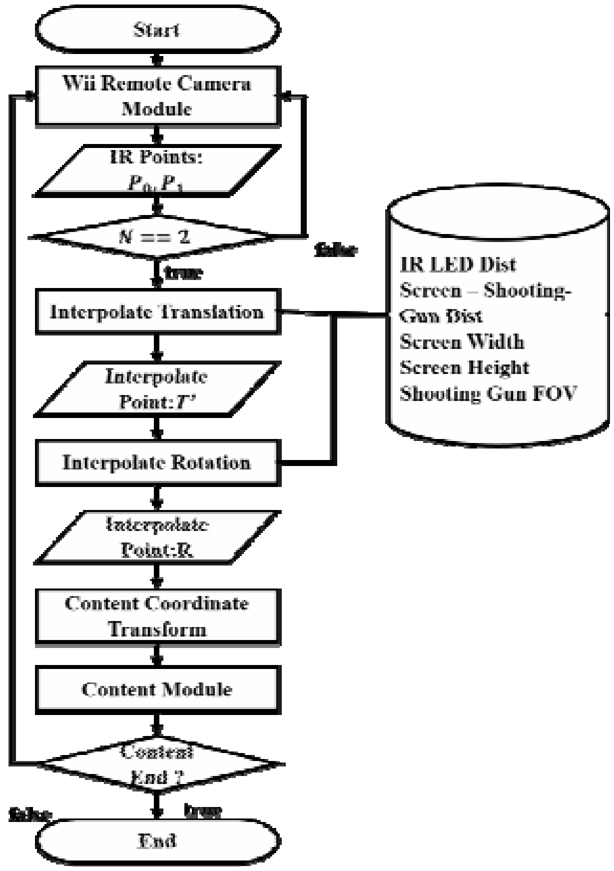

Fig. 7. Interpolation.

distance from the middle of the screen to the shooting gun, the height and width of the screen, and the FOV including the optical lens. These referred values are supposed to be inputted before applying the correction algorithm. Based on the inputted reference values, the correction algorithm begins to work.

8. Correction of the Origin Coordinates

The correction of the origin is a procedure to correspond the infrared LED coordinate recognized by the camera coordinate system with the screen coordinate system. It receives the infrared LED coordinates $P_0(x_0, y_0)$, $P_1(x_1, y_1)$ at the camera module and then computes the median value c using [Formula 3] [8, 11].

$$\left(\frac{(x_0 - x_1)}{2}, \frac{(y_0 - y_1)}{2}\right) = c(c_x, c_y) \tag{3}$$

The error between the origin O_s of the screen coordinate system and the origin O_c of the camera coordinate system is computed using [Formula 4] and the correction of the origin is processed using [Formula 5] [10].

$$\boldsymbol{O_s} - \boldsymbol{O_c} = \vec{t} \tag{4}$$

$$\begin{bmatrix} c_x & c_y & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix} = \begin{bmatrix} T_x & T_y & 1 \end{bmatrix} \tag{5}$$

9. Correction of the Shift Rate of the Aiming Point

When the aiming point shifts, the need for correction arises because the shifting unit rate of the screen coordinate system differs from that of the camera coordinate system. The shift rate is adjusted by referring to the straight distance of the infrared LED. The straight distance of the infrared LED has a value of 1 as a reference rate, when the image range of the Wiimote camera sensor is the same as the range of the infrared LED [Fig. 8].

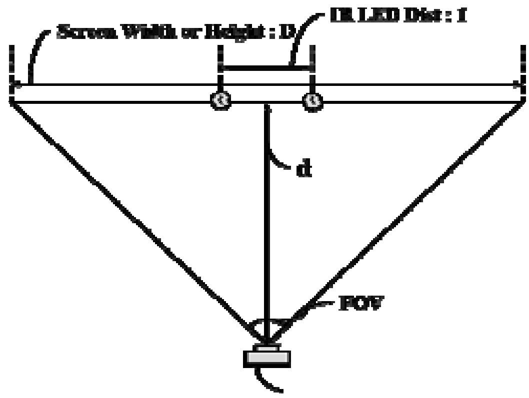

Fig. 8. Screen with the IR LED distance.

The reference rate is used as the scale value when converting the height and width of the infrared LED to the content coordinate system [Formula 6].

$$\begin{bmatrix} T_x & T_y & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ r_{width} & r_{heighty} & 1 \end{bmatrix} = \begin{bmatrix} T_x' & T_y' & 1 \end{bmatrix} \tag{6}$$

If the distance between the screen and the Wiimote camera sensor (Fig. 8, d) is closer than the reference rate, the recognition range of the LED increases and decreases in the opposite case [Fig. 9].

T_x and T_y, the output of Wiimote camera coordinates, are converted to the content coordinates, T_x' and T_y', after applying the value of the width rate, S_{width}, and the height rate, S_{height}.

10. Rotation Correction

When the shooting gun is tilted as in [Fig. 10], the rotation error λ occurs between the camera coordinates and the screen coordinates. In the process of the rotation

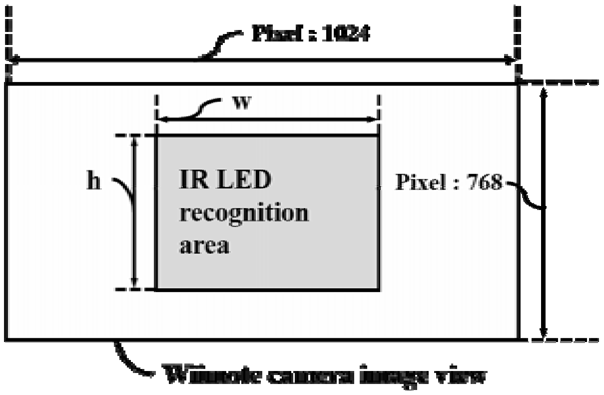

Fig. 9. IR LED recognition area.

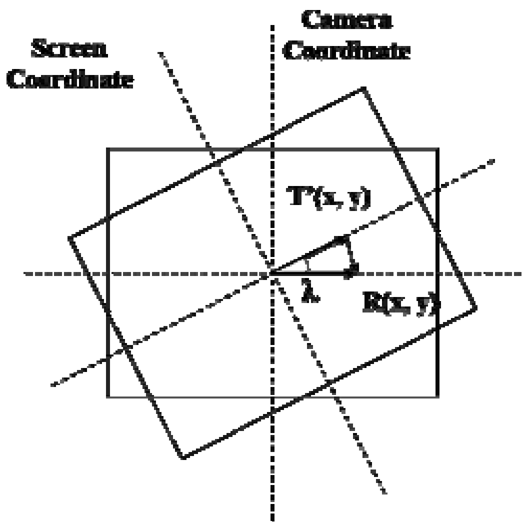

Fig. 10. Rotation error.

correction, T', is corrected into R by [Formula 8] [Figs. 10 and 11] [5, 6].

$$\lambda = atan\left(\frac{b}{a}\right) \tag{7}$$

$$\begin{bmatrix} \cos(\lambda) & \sin(\lambda) \\ -\sin(\lambda) & \cos(\lambda) \end{bmatrix} \begin{bmatrix} T_x' \\ T_y' \end{bmatrix} = \begin{bmatrix} R_x \\ R_y \end{bmatrix} \tag{8}$$

The value of λ was acquired by substituting the infrared LED P_0 and P_1 into a trigonometric function [Formula 7] [Fig. 11] [9].

11. Experimental Setup

The size of the screen was configured to have a width of 6000 mm and a height of 3000 mm. The position of the shooting gun was separately measured to be 2000mm, 3000mm and 4000mm while its height was fixed to 1500mm off the ground. To enhance the accuracy of the experiment, the shooting gun was fixed at the tripod and the laser pointer was set up toward the line of sight. The

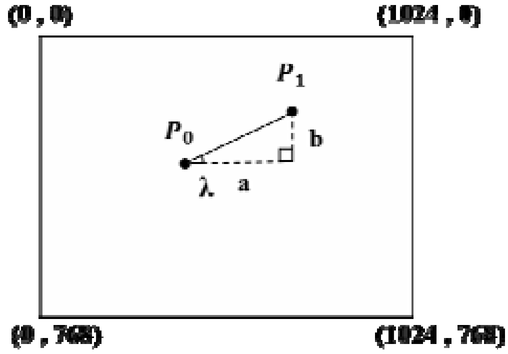

Fig. 11. λ .

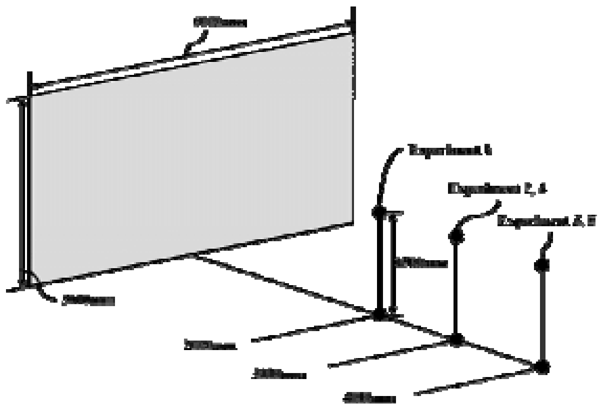

Fig. 12. Experimental Frame.

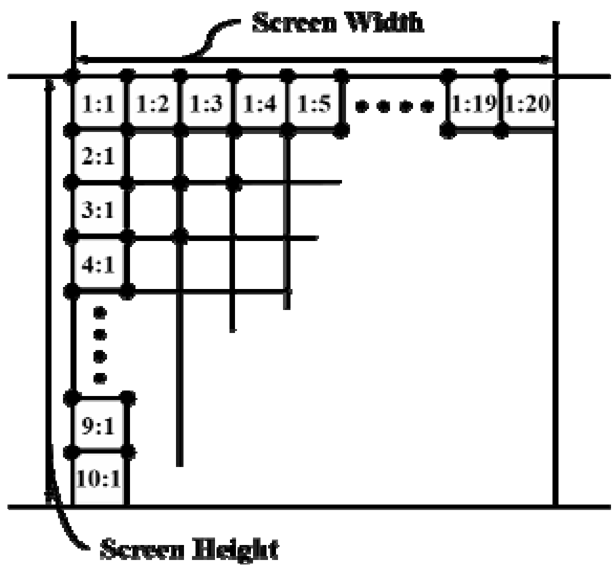

Fig. 13. Screen Grid.

shooting gun's angle of view was set according to the result of measurement, a width of 100° and a height of 90° [Fig. 12].

The aiming point was set to 20 by 10 grids in the screen. Each grid was 300mm x 300mm and the top left-hand corner was used as the aiming point [Fig. 13].

Regarding the aiming point, the grid image with a width of 300mm and a height of 300mm was used. In the experiment, shooting was conducted in consecutive order, from the top left-hand corner to the bottom right-hand corner of the screen. The aimed shooting was carried out to correspond to the aiming point with a laser pointer. Considering the aiming error, in the same circumstance, the average measures after shooting ten-shots was taken as the point of impact. As a result of the experiment, the difference in distance between the actual aiming point and the impact point was normalized in the range of 0 and 2. The rotation correction was processed separately under the conditions of 45° and -45° [Fig. 14] [7].

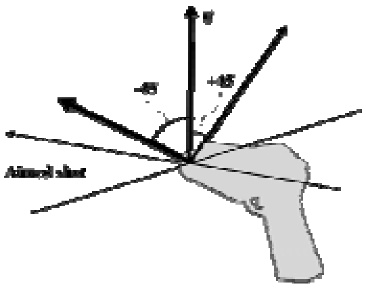

Fig. 14. Shooting Gun Rotation.

12. Experimental Results

[Figs. 15-17] show graphs representing the value of the average error of the impact point in height compared to the aiming point in width. As a result of the user-experiencing experiment, the reference value was set up as 300mm. In terms of the error value, it was set to 1 referring to 300mm and normalized between 0 and 2.

As shown in [Figs. 15-17], the rate of error increases with increasing distance from the center of the screen. This is the error caused by a distortion of the optical lens set in front of the camera module. Nevertheless, this is an acceptable level as there was no data beyond the error rate of 1.

A comparison of the average error rate according to the distance between the screen and the shooting gun revealed 0.31 at 2000mm and 0.42 at 4000mm, showing no significant change.

[Figs. 18, 19] present the results when tilted by 45° in the left and right side at a distance of 3000mm. Compared to the condition of 0° rotation, it generally shows higher error rates. The process of rotation correction the round-off error

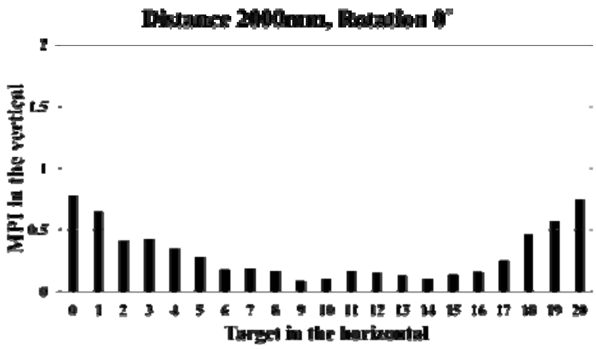

Fig. 15. Distance 2000mm, Rotation 0°.

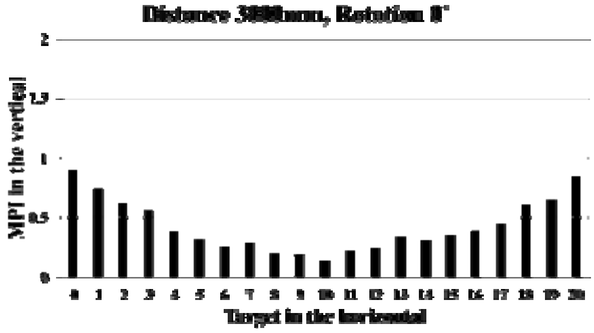

Fig. 16. Distance 3000mm, Rotation 0°.

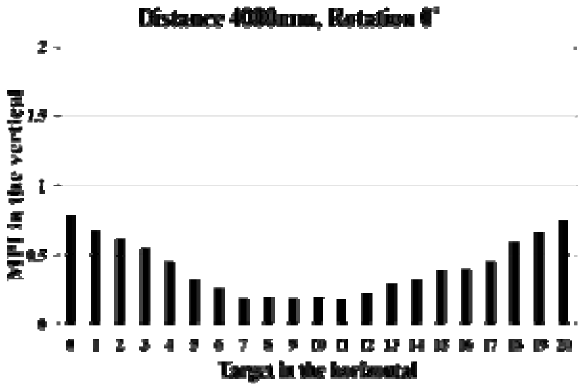

Fig. 17. Distance 4000mm, Rotation 0°.

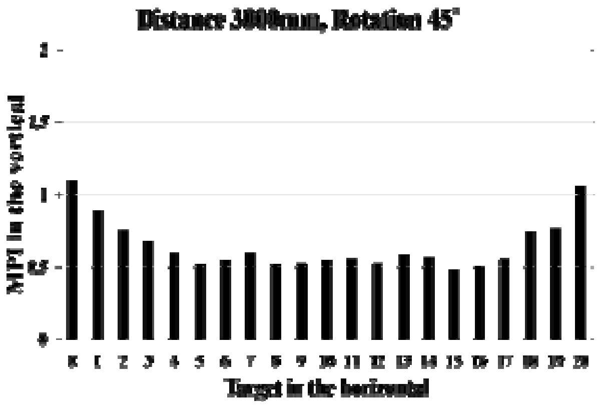

Fig. 18. Distance 3000mm, Rotation 45°.

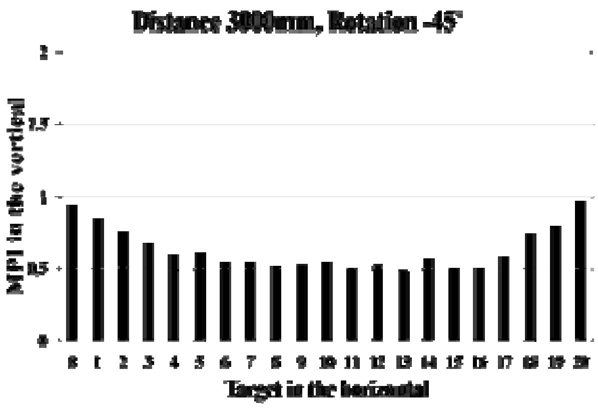

Fig. 19. Distance 3000mm, Rotation -45°.

of trigonometric function appears to affect the error rate.

13. Conclusion

This paper established an infrared LED-based shooting gun system that rectified the disadvantage of a conventional arcade, and proposed an interpolation algorithm that could be used adaptively in a range of environments.

This paper describes 3 steps of the interpolation process to make the aiming point coincide with the point of impact according to the size of the screen and the distance between screen and shooting gun. The error rate occurred within the value that user can accept in the experiment results according to each step of interpolation.

The error rate is caused mainly by wide-angle lens distortion and round-off error that occurs in the process of interpolation, and it is essential to develop a step of wide-angle lens distortion correction and an algorithm to obtain a stable interpolation value. In addition, future research will examine applications to various screens with a curved surface and dome shape as well as flat screens with a rectangular shape.

Acknowledgement

This work was supported by the Brain Busan 21 Project in 2014

References

[1] G. Marfia, A. Amoroso, M. Roccetti, G. Basile, Palazzi, E. Claudio "Video Games at the Library: A Historical Perspective" IEEE, July 31 2011-Aug. 4 2011, pp.1-6 Article (CrossRef Link)

[2] P. Wallich, "Building your own arcade game [Hands On]" IEEE, July 2011, pp.26-27. Article (CrossRef Link)

[3] Lee, Johnny Chung. "Hacking the nintendo wii remote." Pervasive Computing, IEEE 7.3 (2008): 39-45.Article (CrossRef Link)

[4] Hoffmann, C.M. Dept. of Comput. Sci., Purdue Univ., West Lafayette, IN, USA "Implicit curves and surfaces in CAGD" IEEE, Jan. 1993, pp.79 – 88. Article (CrossRef Link)

[5] Shih, Sheng-Wen, Yi-Ping Hung, and Wei-Song Lin. "Accuracy analysis on the estimation of camera parameters for active vision systems." Pattern Recognition, 1996., Proceedings of the 13th International Conference on. Vol. 1. IEEE, 1996. Article (CrossRef Link)

[6] Lenz, Reimar K., and Roger Y. Tsai. "Techniques for calibration of the scale factor and image center for high accuracy 3-D machine vision metrology." Pattern Analysis and Machine Intelligence, IEEE Transactions on 10.5 (1988): 713-720. Article (CrossRef Link)

[7] D. Weng, D. Li, W. Xu, Y. Liu, Y. Wang Beijing Institute of Technology "AR Shooter: An Augmented Reality Shooting Game System" IEEE, 13-16 Oct. 2010, pp.311 Article (CrossRef Link)

[8] Rongqian Yang; Dept. of Biomed. Eng., South China Univ. of Technol., Guangzhou, China; Wei Yang; Yazhu Chen; Xiaoming Wu "Geometric Calibration of IR Camera Using Trinocular Vision" IEEE, Dec.15, 2011, pp.3797 – 3803. Article (CrossRef Link)

[9] Nowakowski, A.; Warsaw Univ. of Technol., Warsaw; Skarbek, W. "Lens Radial Distortion Calibration Using Homography of Central Points" IEEE, 9-12 Sept. 2007, pp. 340-343. Article (CrossRef Link)

[10] Zhen Duo; Dept. of Telecommun. Syst., Commun. Univ. of China, Beijing, China; Wenhui Zhang "Constructing 3D position tracking system with Twin-Wiimote Structure" IEEE, 20-21 Oct. 2012, pp. 466-469. Article (CrossRef Link)

[11] Petrič, T.; Dept. of Autom., Biocybernetics & Robot., Jozef Stefan Inst., Ljubljana, Slovenia; Gams, A.; Ude, A.; Žlajpah, L. "Real-time 3D marker tracking with a WIIMOTE stereo vision system: Application to robotic throwing" IEEE, 24-26 June 2010, pp. 357-362. Article (CrossRef Link)

YoSeph Choi received his B.S degree in Dept. of Game in Digital Contents from Dongseo University, South Korea, in 2013. Currently he is a master student at the Division of Visual Contents from Dongseo University, South Korea. His research interests include virtual reality, game development and natural user interfaces.

DuCheol Kang DuCheol Kang is a researcher of the Arcade Game Regional Innovation center (AGRIC) in Dongseo Univ. He received his B.S and M.S degrees in Multimedia science and Division of Visual Contents from Dongseo University, South Korea, in 1993 and 2001, respectively. His research interests include computer vision virtual reality, game development and natural user interfaces.

TaeSoo Yun is a Professor of Digital Contents at the Dongseo University, he is the chief of the Arcade Game Regional Innovation Center(AGRIC) in Dongseo Univ. He received his B.S degrees and M.S degrees and Ph.D in computer science from Kyungpook National University, South Korea, in 1991, 1993 and 2001, respectively. His research interests include machine vision and computer vision, image processing, virtual reality and game development.