DETECTING LASER POINTER IN THE SHOOTING SIMULATOR USING EMBEDDED CAMERA BASED-ON OMNIVISION OV6620

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ABSTRACT: The paper presents the development of shooting simulator using the embedded camera based-on Omnivision OV6620. The proposed system provides a simple and low cost embedded system to detect the laser spot in the shooting simulator. The proposed system employs the circular target as the shooting target. The embedded system is installed inside the target box behind the target screen. Once the target screen is illuminated by the laser spot, the embedded camera detects the position of laser spot, and sends the position to the computer for calculating the shooting score. The color tracking is performed in the embedded system by comparing the values of red, green, and blue colors with the thresholds defined in advance. The experimental results show that the system could calculate the shooting score properly. Further, to provide an easy calibration of the camera's position, the computer could read a whole image captured by the camera for further processing.

Keywords: Shooting simulator, Laser pointer, Embedded camera, OV6620

1. Introduction

The laser pointer is widely used as a pointer for many applications, such as the pointer in large display interaction (Kim, Lee, Lee, and Lee, 2007; Lapointe, and Godin, 2005; Pavlovych, Stuerzlinger, 2004; Widodo, Chen, and Matsumaru, 2012), the archery sport (Chandrapal, Senanayake, and Suwarganda, 2009), and the shooting simulators (Ladha, Miles, Chandran, 2013; Liang and Kong, 2006; Soetedjo, Mahmudi, Ashari, Nakhoda, 2014; Soetedjo, Mahmudi, Ashari, Nakhoda, 2015; Soetedjo, Nurcahyo, Prawida, 2013). This paper addresses a system to detect the laser pointer used in the shooting simulators. The shooting simulator is an apparatus for shooting practice that replace the bullet with other aimed instrument such as the laser spot. Basically there are two types of the devices to detect the laser spot i.e. using the photo-detector (Soetedjo, Nurcahyo, Prawida, 2013) and the camera system (Ladha, Miles, Chandran, 2013; Liang and Kong, 2006; Soetedjo, Mahmudi, Ashari, Nakhoda, 2014; Soetedjo, Mahmudi, Ashari, Nakhoda, 2015). A photodiode array was employed to detect the laser spot (Soetedjo, Nurcahyo, Prawida, 2013). The photodiodes were arranged in a circular pattern as the target shooting. The shooting score was calculated based-on the ring position of the photodiode which was active when aimed by the laser spot from the shooter.

Due to the fast development in the machine vision system, the shooting simulator based-on the camera system is commonly adopted. The camera systems were installed on the shooting target to detect the laser spot (Liang and Kong, 2006; Soetedjo, Mahmudi, Ashari, Nakhoda, 2014). While the camera systems were installed on the gun called as sensor on weapon system (Ladha, Miles, Chandran, 2013; Soetedjo, Mahmudi, Ashari, Nakhoda, 2015).

In the machine vision system, the algorithm and the computer hardware are the issues should be considered. The personal computer is a powerful processor to perform the image processing tasks (Ladha, Miles, Chandran, 2013; Liang and Kong, 2006), but the flexibility is low due to the size and complexity. To provide a flexible system, the embedded camera systems were employed to detect the laser spot (Soetedjo, Mahmudi, Ashari, Nakhoda, 2014; Soetedjo, Mahmudi, Ashari, Nakhoda, 2015).

An embedded camera CMUCam4 was installed inside a target box to detect the red laser spot on the target screen in front of the box (Soetedjo, Mahmudi, Ashari, Nakhoda, 2014). Since the camera was installed inside the box, the lighting condition could be controlled, thus the problem of illumination changes could be avoided. An embedded camera system based-on Raspberry Pi module was installed on the gun that emitted the laser spot to the target (Soetedjo, Mahmudi, Ashari, Nakhoda, 2015). The benefit of the system is that the user or shooter could use the flexible shooting target. While the main drawback is the influence of the lighting changes, which affects the accuracy of laser spot detection.

In this paper, we propose a low cost embedded camera system to detect the laser spot. The propose method is the low cost version of the one developed previously (Soetedjo, Mahmudi, Ashari, Nakhoda, 2014). The embedded camera system is developed based on the OmniVision OV6620 camera and the ATMega microcontrollers. Further, a GUI is developed to initialize the camera system and monitor the shooting score.

The rest of paper is organized as follows. Section 2 presents the proposed method. Section 3 describes the experimental results. Conclusion is covered in Section 4.

2. Proposed System

The architecture of proposed system is similar to our previous work (Soetedjo, Mahmudi, Ashari, Nakhoda, 2014), where the system consists of three main components: a) Target box with circular pattern as the shooting target; b) A gun equipped with the laser pointer; c) A personal computer to monitor the shooting score. This paper differs from the previous one in the embedded camera system installed in the target box.

The system works as follows. When the shooter aims a gun (laser pointer) into the target box, the target screen with circular pattern (see Figure 1) will be illuminated with the laser spot. Since the screen is made from a thin paper, the laser spot will go through the screen and could be captured by the camera inside the box. Then, the camera system detects the appearance of laser spot and locates the position of the spot. Finally, the shooting score is determined based on the position of laser spot in the circular ring, where the outer position is given the lower score.

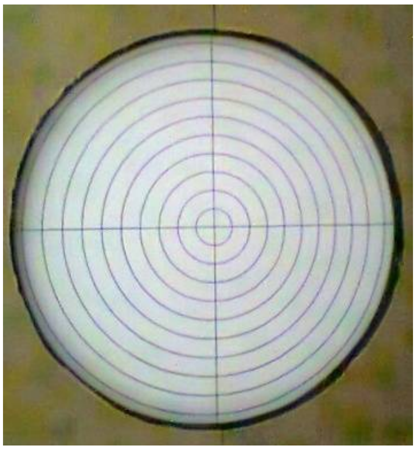

Figure 1 Target screen with circular pattern

2.1 Hardware Configuration

The hardware configuration discussed in this section is the embedded camera which is installed inside the target box. The block diagram of an embedded camera is illustrated in Figure 2. The main components are a camera module OV6620 and two ATMega microcontrollers. The ATMega8 microcontroller is used to control the initialization process of OV6620 and provide reset signal to the ATMega32 microcontroller. The ATMega32 microcontroller is clocked by the external clock from OV6620, thus both modules are easy to be synchronized. The image data from OV6620 are read by ATMega32 microcontroller via parallel bus and connected to the digital ports of microcontroller.

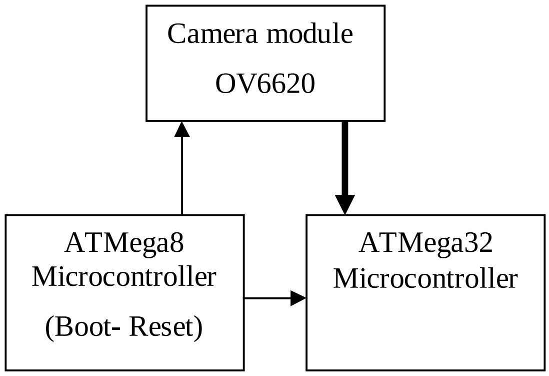

Figure 2 Block diagram of embedded camera

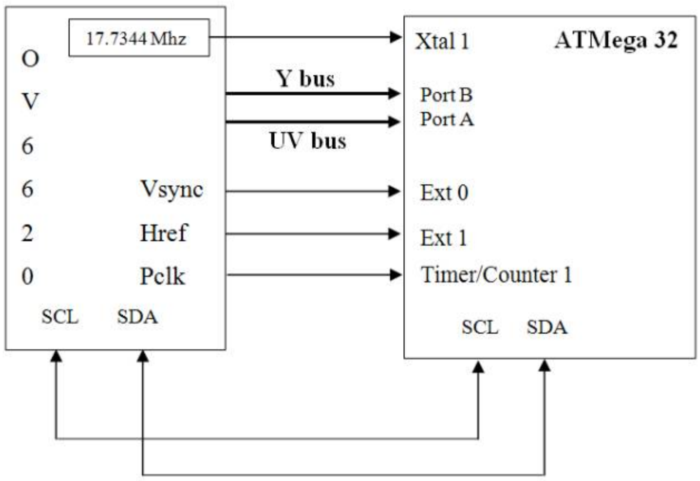

Figure 3 Connection between OV6620 and ATMega32 microcontroller

Figure 3 illustrates the connection between OV6620 and ATMega32 microcontroller. As shown in the figure, the clock signal input of ATMega32 microcontroller is a 17.7344 MHz clock signal generated by OV6620. The image data are transferred via the Y bus for red color, and UV bus for green and blue colors, where the Y bus and UV bus are connected to Port-B and Port A of the ATMega32 microcontroller respectively. The Vsync signal is connected to the external interrupt-0 of ATMega32 and used for vertical synchronization. The Href signal is connected to the external interrupt-1 of ATMega32 and used for horizontal synchronization. The Pclk signal is the pixel clock that indicates the valid data. It is connected to the Timer/Counter-1 of ATMega32. The I^2C data (SDA and SCL) are used to set the registers in OV6620.

2.2 Software Configuration

Figure 4 illustrates the flowchart of main program in the embedded system. There are three main subroutines, i.e. “Get picture”, “Set color tracking parameter”, and “Get color tracking”. In the “Get picture” subroutine, the picture is read from the camera module (OV6620), then it is sent to the computer via serial communication. The data format is given in Table 1. The picture resolution is 176 x 144 pixels (QCIF: Quarter Common Interchange Format). The “Set color tracking parameter” subroutine is used to set the parameter for color tracking, i.e. the lower and upper threshold’s values of each red, green, and blue colors. The “Get color tracking” subroutine is used to get the coordinates of color tracked object. The color tracking is a simple color thresholding, where a pixel is tracked if the values of red, green, and blue components fall in the range of the lower and upper thresholds of the respective color.

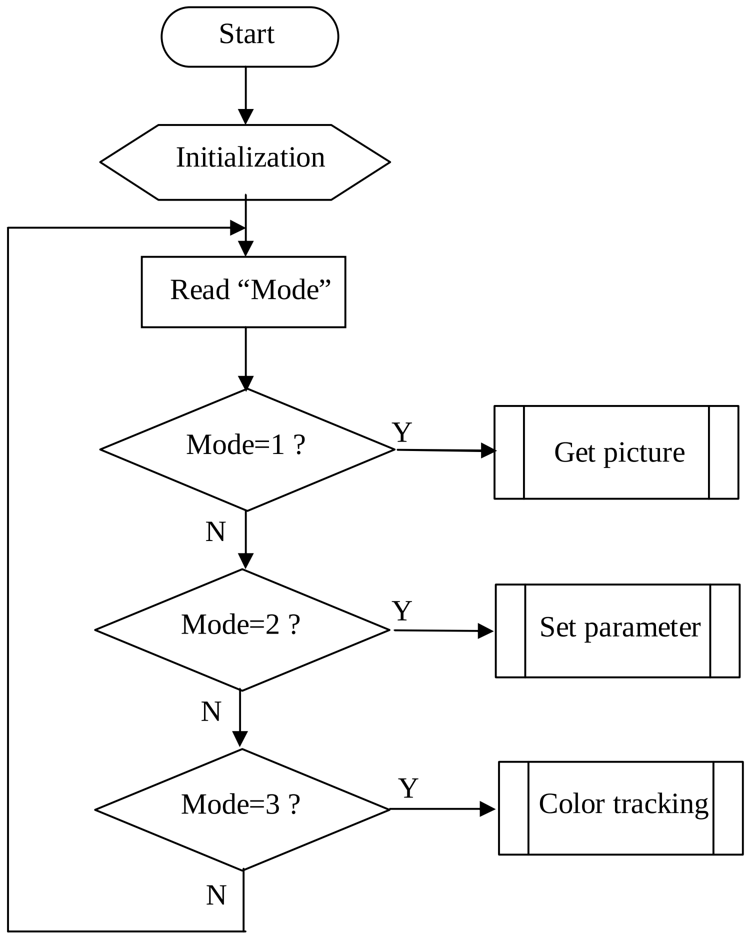

Figure 4 Flowchart of main program

The shooting score is calculated based-on the position of laser spot in the circular target using Eq. (1) (Soetedjo, Mahmudi, Ashari, Nakhoda, 2014).

$$Score = 10 - \left(\left(10 \times \sqrt{\left(Cx_l - Cx_t\right)^2 + \left(Cy_l - Cy_t\right)^2} \right) / r \right) \quad (1)$$

where Cx_t and Cy_t are x-coordinate and y-coordinate of the center of circular target respectively; Cx_l and Cy_l are x-coordinate and y-coordinate of the center of laser spot respectively; r is radius of the circular target.

Table 1 Data format in "Get picture" sub-routine.

No. of byte	Data	Remark
Byte-1	0x0F	Header
Byte-2	Number of line (in hexadecimal)	0x01 to 0x90 (144 rows)
Byte-3	Color of pixel in 1st column	Green = high nibble Blue = low nibble
Byte-4	Color of pixel in 2nd column	Green = high nibble Red = low nibble
…	….	…
Byte-178	Color of pixel in 176th column	Green = high nibble Red = low nibble

3. Experimental Results

The hardware of embedded camera system is depicted in Figure 5, where the camera module OV6620 is located in the center of board. The ATMega32 is located in the left side of the OV6620, while the ATmega8 is located just below the OV6620. The serial RS-232 to USB converter is used to convert the serial RS-232 to the USB port of computer for serial communication.

Figure 5 Hardware implementation

Figure 6 depicts the picture of inside part of circular target captured by the camera system, which is sent to the computer via the serial communication. This result is obtained by sending the command mode of 1 ("Get picture") to the embedded system. By reading the image, the calibration of camera position could be done easily.

The main objective of the system is to perform color tracking of the laser spot. The color tracking is determined by setting the threshold of each color using the GUI interface as shown in Figure 7. The thresholds are set using the sliding bar, where each color has the minimum and maximum threshold values. From a few experiments, the thresholds for detecting or tracking the laser spot are found as follows. The red component has the minimum and maximum threshold values of 199 and 240 respectively. The green component has the minimum and maximum threshold values of 208 and 240 respectively. The blue component has the minimum and maximum threshold values of 208 and 240 respectively.

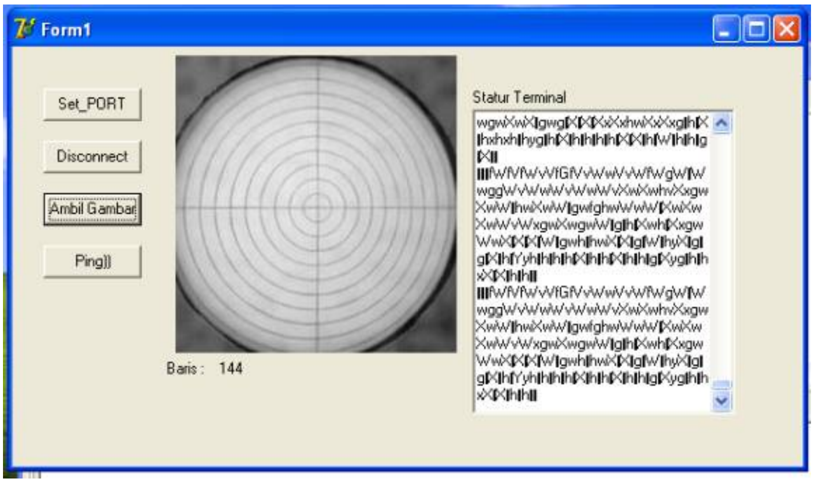

Figure 6 Picture of target pattern captured by the camera module.

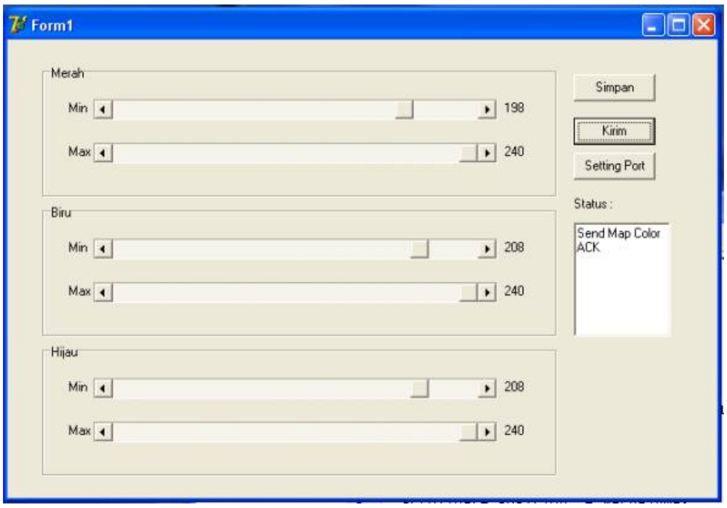

Figure 7 Menu for setting the color tracking parameter.

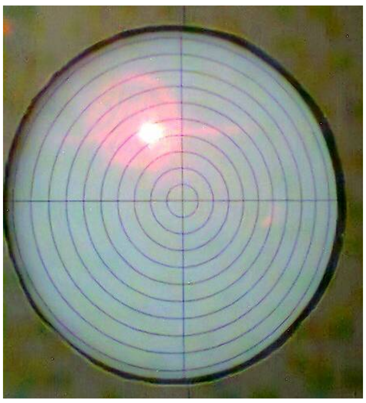

Figure 8 Menu for setting the color tracking parameter

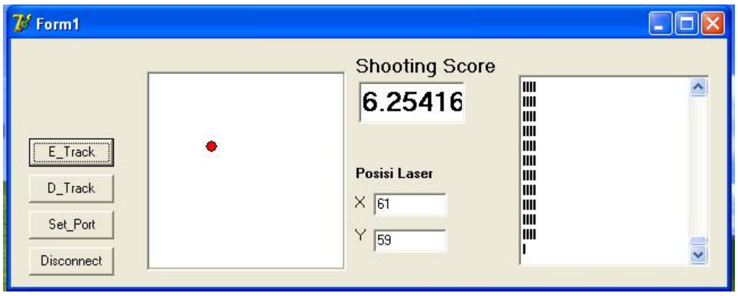

Figure 9 Shooting score displayed in the computer monitor

The result of laser spot detection is illustrated in Figure 8 and 9. In Figure 8, the laser spot illuminates the circular target in front of the target box. As shown in the figure, the laser spot is located on the 6^{th} ring from the outer ring. In Figure 9, the shooting score is displayed as 6.25416. From the results, it is clear that the algorithm implemented in the embedded system could determine the position of laser spot and calculate the shooting score properly. Observing Figure 8, it is obtained that when the red laser pointer hits the target screen, the red color illuminates in the outlier part of laser spot. The center part of laser spot is a white color. It conforms with the threshold values obtained previously, which representing the range of white color.

4. Conclusion

The camera module OV6620 is employed as the embedded camera system to detect the laser spot in the shooting simulator. Two ATMega32 and ATMega8 microcontrollers are employed to interface with the camera module, where the first microcontroller performs the main function for reading the image, while the second microcontroller is used for initialization process and providing the reset signal to the ATMega32 microcontroller. The experimental results show that the developed system is a low cost system that is suitable for this application. In future, the system will be expanded to handle the different types of the shooting target. Further, the reliability of the system will be improved for the real application.

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