Aryu_Proceeding_2014-2.pdf

by

2014 2nd International Conference on Technology, Informatics, Management, Engineering & Environment
Bandung, Indonesia, August 19-21, 2014

Implementation of Sensor on the Gun System Using Embedded Camera for Shooting Training

Aryuanto Soetedjo
Department of Electrical Engineering
National Institute of Technology (ITN)
Malang, Indonesia
aryuanto@gmail.com

Ali Mahmudi
Department of Informatics Engineering
National Institute of Technology (ITN)
Malang, Indonesia

M. Ibrahim Ashari
Department of Electrical Engineering
National Institute of Technology (ITN)
Malang, Indonesia

Yusuf Ismail Nakhoda
Department of Electrical Engineering
National Institute of Technology (ITN)
Malang, Indonesia

***Abstract*—This paper presents the implementation of an embedded camera system applied for shooting training, where the sensor on the gun system is adopted. A CMUcam4 is attached on the gun to detect the laser spot emitted by the shooter. In addition, the camera is used to detect the coordinates of marker on the target, which are sent to a computer for calculating the homography transform. A simple color thressholding is employed on the camera for such detection. Experiment results show that the errors of marker and laser spot detection are 2.33% and 2.15% respectively. The computer system helps to calculate the homography transform properly. Therefore the shooting point could be determined accurately, regardless of the position and viewing angle of the camera.**

Keywords-shooting training; sensor on the gun; CMUcam4; homography.

I. INTRODUCTION

It is common to employ the camera vision systems in the shooting training, in which the camera is used to capture the laser spot emitted by the shooter. Generally, it is divided into two methods [1]: a) Single camera stationary system; b) Sensor on the gun system. In the first system, a camera is installed on a fixed position in front of shooting target. An image processing technique is applied to detect the laser beam for locating the hit point on the target [1,2]. In the second system, a camera is attached on the gun. Thus the camera moves along the shooter's movement [1,3,4].

The limitation of the camera stationary system is that it is difficult to distuingish the shooting points when the multiple shooters shoot a single target. In sensor on the gun system, the direction of shooting could be recognized easily due to the fact that a camera is alligned on the gun. Thus the above problem could be resolved [1]. In [1,2], the shooting point is considered as the center point of captured image.

The most challenging task on both systems is how to locate the shooting point accurately. It involves two major problems, i.e. : a) Detecting laser spot on the target; and b) Determining the proper location of laser spot on the target image due to the camera perspective. To detect laser spot, several techniques have been proposed [2,4,5,6,7,8]. The thresholding methods were employed in the intensity images [5], RGB color images [2,4], and HSV color images [6,7].

To correct the distorted images due to the camera projection, the homography techniques are used. In [2], the view angle of camera was considered very small, thus an affine transformation was employed. Three points on the target were used to solve the transformation matrix. In [3,6], four points were used to find the homography matrix. Since the position of camera is fixed, the homography transformation was calculated once at the callibration stage [2,6]. However, in the moving camera system (sensor on the gun system), thus transformation should be calculated each time the gun is fired [3].

The previous sensor on the gun systems as described above employ the Web-Camera or USB-Camera as the camera sensor. Therefore the USB cable should be used to connect the camera and computer system. It might restrict the movement of shooter. To overcome this limitation, we propose the sensor on the gun system using an embedded camera. In the proposed system, the embedded camera is connected to the computer using a wireless network. Since the embedded system is employed, the simple and efficient color thresholding techniques are adopted to detect the laser spot and markers for homography calculation. Compared to the existing techniques, our proposed system has several advantages, such as: a) It provides more flexibility to the shooter; b) It uses the commercial components, thus it could be assembled easily; c) It does not need the complicated calibration process.

The paper is organized as follows. Section 2 describes the system configuration. Section 3 describes the shooting detection techniques. Section 4 discusses the experiment results. Conclusions are covered in section 5.

II. SYSTEM CONFIGURATION

Fig. 1 shows the configuration of proposed sensor on the gun system. It consists of three main parts, i.e. shooting target, gun, and computer. The gun is equipped with a laser pointer, an embedded camera, and a wifi module. The target could be an image projected by a projector system or a picture printed on a piece of paper.

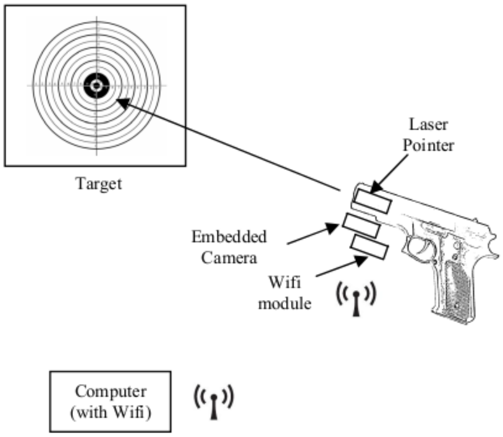


Figure 1. System configuration.

A CMUcam4 [8] is employed as the embedded camera. It uses the Parallax P8X32A (Propeller Chip) as the main processor and an OmniVision 9665 as the CMOS camera sensor. The module is able to perform color tracking of the 160x120 color image at 30fps. A serial communication is provided to exchange the data between CMUcam4 and external devices. A wifi module is used to communicate between CMUcam4 module and the computer.

The computer is used to display the tracked laser spot and calculating the homography transformation for determing the shooting point accurately as described in the next section.

III. SHOOTING DETECTION

In the proposed sensor on the gun system, shooting detection is carried out by detecting the laser spot and determining the position of laser spot (shooting point) on the target. Since the camera is attached on the gun, the captured image will produce the homography due to the camera rotation and translation.

Fig. 2 shows the shooting detection process. At first, the camera captures the target image. Then it will detect the four points marker on the target for homography calculation. After detecting marker, the camera will detect the laser spot on the target. When the laser spot is detected, it sends the detected coordinates (both marker and laser spot) to the computer.

The computer calculates homography matrix using the four points data sent by the embedded camera. Once the homography matrix is obtained, the new transformed image is calculated. Finally, the location of shooting point is determined based on this corrected image.

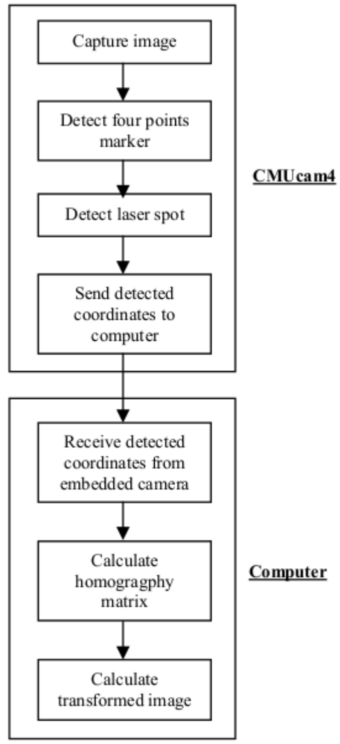


Figure 2. Shooting detection process.

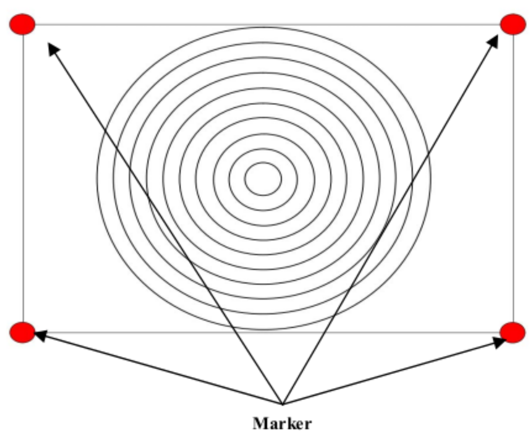


Figure 3. Shooting target with marker.

A. Target and Laser Spot Detection

Similar to [3], our proposed system uses four points on the target for calculating homography matrix. The shooting target could be any pictures. The only requirement is the four small solid circles should be drawn on four corners as shown in Fig. 3. The circles are painted in red colors, thus they could be detected by the CMUcam4 easily.

To detect the red solid circles, a simple color thresholding is employed as expressed by the following equation:

$$If\,(R_{\min} \le R(x,y) \le R_{\max})\; AND\,(G_{\min} \le G(x,y) \le G_{\max})$$
$$AND\,(B_{\min} \le B(x,y) \le B_{\max})\; THEN\; pixel(x,y)\, is\; RED \qquad (1)$$

where *R(x,y)*, *G(x,y)*, *B(x,y)* are the red, green, blue components of *pixel(x,y)* respectively; R_{min} , G_{min} , B_{min} , R_{max} , G_{max}, B_{max} are the thresholds. In the experiments, the values of thresholds are R_{min}=100 , G_{min}=0 , B_{min}=0 , R_{max}=255, G_{max}=120, B_{max}=120.

The laser spot is detected using the following equation:

$$If\,(LR_{\min} \le R(x,y) \le LR_{\max})\; THEN\; pixel(x,y)\, is\; LASER\; SPOT \qquad (2)$$

where the thresholds are LR_{min}=250 and LR_{max}=255.

In some situations, the simple color thresholding detects the reddish objects that are not belong to the marker nor the laser spot. To overcome the problem, we propose the searching windows while applying the color thresholding. The searching windows are illustrated in Fig. 4. This approach takes the advantage of sensor on the gun system, where the center of captured image will be the shooting point. Therefore the four red points will be on the top-left, top-right, bottom-left, bottom-right of the captured image as shown in the figure. While the searching window for laser spot detection is on the center of image.

Using the searching windows, the color thresholding is applied on a small area only. Thus the false detection could be minimized. This strategy ensures that the shooter aims the gun on the viewing area of camera.

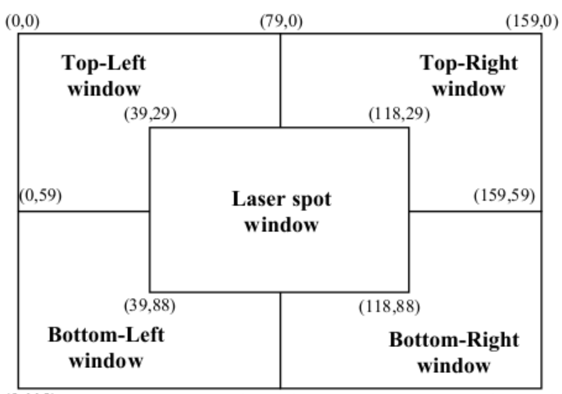


Figure 4. Searching window.

B. CMUcam4 Color Tracking

The CMUcam4 is an embedded vision system developed by Carnegei Mellon University [8]. The module is easy to used and equipped with the algorithm for color tracking. The color tracking works by scanning pixels from top left of the image row by row. The pixels are considered as the tracked pixels if the colors are inside the color range as described in (1). At the end of scanning, the middle (centroid) coordinates of tracked object are calculated. The coordinates of bounding box of tracked object are also found.

The CMUcam4 could be controlled by sending ASCII command via the serial communication line. To do the color tracking, the command of "TC [red min] [red max] [green min] [green max] [blue min] [blue max] '\r' " should be issued, where red min, red max, green min, green max, blue min, and blue max are the color ranges of tracked object. The module replies with following data: "T mx my x1 y1 x2 y2 per_pixels per_confidence '\r' ", where mx, my are the centroid coordinates of tracked object, x1, y1, x2, y2 are the coordinates of bounding box of tracked object, per_pixels is the percentage of the numbers of tracked pixels, per_confidense is the percentage of the numbers of tracked pixels in the bounding box.

C. Homography

Fig. 5 illlustrates the homography transform, where Fig. 5(a) shows the normal camera view and Fig. 5(b) shows the rotated camera view. The relationship between the coordinates on both images are expressed using 3x3 homography matrix as follows:

$$\begin{bmatrix} u \\ v \\ w \end{bmatrix} = H \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \qquad (3)$$

The matrix H could be solved when four points are known. In the research, four points are the centroid coordinates of red solid circles as shown in Fig. 3.

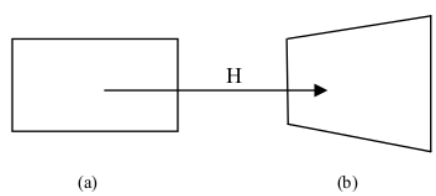


Figure 5. Homography transform : (a) Normal camera view ; (b) Rotated camera view.

IV. EXPERIMENT RESULTS

Several experiments are conducted to verify the proposed system. In the experiments, the built-in color tracking of CMUcam4 is employed to detect the marker and laser spot. The CMUcam4 tracks the color on the image with resolution of 160x120 pixels.The homography transform is implemented using MATLAB on a personal computer. The MATLAB code for calculating the homography is taken from Machine Vision Toolbox [9].

Two cases are observed during experiments, i.e. the color detection errors and homography calculation. The color detection error is calculated by comparing the centroid coordinates obtained by the embedded camera and the manual inspection (by utilizing an image editor tool) of the captured images.

To evaluate the errors of red marking detection, seven shooting attempts with the different shooting angles are conducted. While five shooting attempts are conducted for evaluating the errors of laser spot detection. The results are listed in Table 1. From the table, it is obtained that the average errors for red marking and laser spot detection are 2.33% and 2.15% respectively.

TABLE I. TRACKING ERRORS

Object tracking	***X- coordinate error***	***Y- coordinate error***
Top-left red circle marking	3%	3.44%
Top-right red circle marking	0.74%	4.9%
Bottom-left red circle marking	3%	1.28%
Bottom-right red circle marking	1.04%	1.29%
Laser spot	2%	2.3%

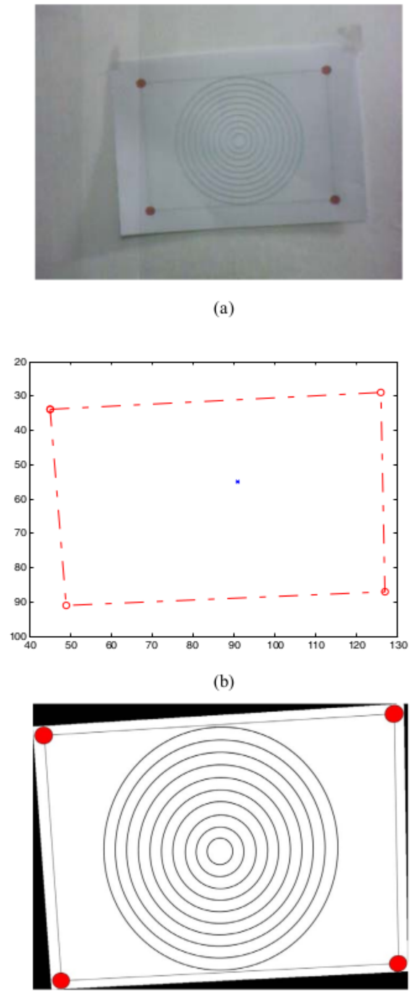
It is worthy to note that the above results are obtained using the small resolution embedded camera system attached to the gun. The detection algorithms are embedded on the CMUcam4 module. Therefore there is no need the USB cable to connect between the gun and computer such as propsed by [1,3]. Using this approach, our proposed sensor on the gun system offers more flexibility to the shooter for handling the gun. This advantage is achieved by two following features: a) The low cost image processing platform; b) The low power microcontroller system. The second feature ensures that the system could be supplied by a battery attached to the gun.

Since a low cost embedded system is employed, it could not calculate the homography transform efficiently. Fortunately, the wireless communication is provided to transfer the tracked data (the coordinates of marker and laser pointer) to the computer. Then the computer is used to calculate the homography and further processes, such as the real-time shooting monitoring and the shooting analysis.

The homograhy calculation is evaluated by observing the captured images and the transformed images obtained by homography transform as shown in Figs. 6-7.

Figs. 6-7 show the experiment results on a circular picture target and an animal picture target, respectively. Fig. 6(a) shows the captured image of the target. As shown in the figure, the image of target which is captured by the camera is not in normal view, due to the position of camera. Fig. 6(b) shows the detected four points as the marker. The four points are used to calculate the homography transform, where the resulted transformed image is shown in Fig. 6(c). From the figure, it is clear that the transformed image matches with the captured image in Fig. 6(a). In Fig. 7, the target background is darker than the one in Fig. 6. The results obtained in Fig.7 are similar to the ones in Fig. 6.

Fig. 8 shows the laser spot detection, where Fig. 8(a) shows the captured image, while the detected laser spot is shown in Fig. 8(b). Comparing Fig. 8(a) and Fig. 8(b), it is clearly shown the laser spot is detected properly.



(c)

Figure 6. Experiment results on a circular picture target: (a) Captured images; (b) Detected marker; (c) Tranformed image by homography tarnsform.

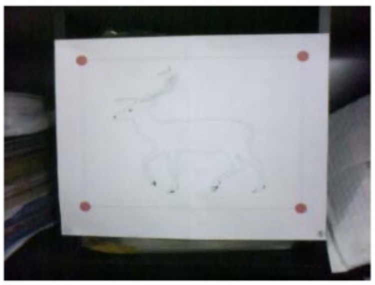
V. CONCLUSIONS

In this work, we have implemented a sensor on the gun system using an embedded camera for shooting training. A low cost CMUcam4 camera is employed as the embedded camera. Experiment results have shown the effectiveness of the proposed system for detecting the laser spot and calculating the homography transform.

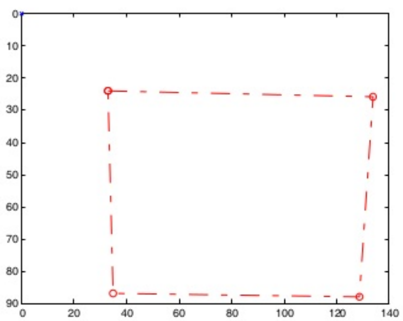
In future, the system will be extended to deal with the complex targets and the backgrounds. Further, the software application for analyzing shooting performance will be developed.

ACKNOWLEDGMENT

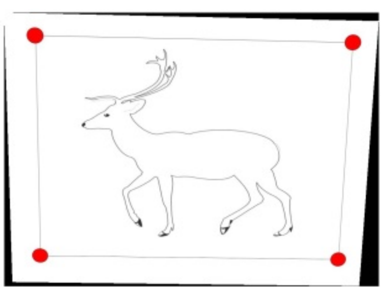
This work is supported by the "National Strategic Research Grant 2014" from Directorate General of Higher Education, Ministry of National Education and Culture, Republic of Indonesia, No. SP-DIPA-023.04.2.415015/2014.



(a)



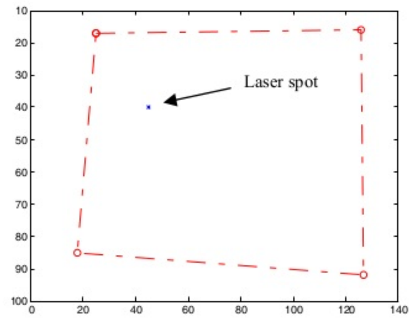
(b)



(c)

Figure 7. Experiment results on an animal picture target: (a) Captured images; (b) Detected marker; (c) Tranformed image by homography tamsform.

(a)



(b)

Figure 8. Laser spot detection: (a) Captured images; (b) Detected laser spot.

REFERENCES

[1] S. Ladha, S. Chandran, K.T. Miles,"Vision assited safety enhanced shooting range simulator," Proceedings of National Conference on Computer Vision, Pattern Recognition, Image Processing and Graphics (NCVPRIPG), Jaipur, India, January 2010

[2] H.W. Liang, B. Kong, "A Shooting Training and Instructing System Based on Image Analysis," Proceedings of the IEEE Conference on Information Acquisition, pp. 961-966, August 20-23, 2006, Shandong, China.

[3] S.L. Ladha, K.S. Miles, S. Chandran, "Multi-User Natural Interaction with Sensor on Activity," Proceedings of 1st IEEE Workshop on User-Centered Computer Vision, pp. 25-30, January15-17,2013, Florida, USA.

[4] A. Soetedjo, M.I. Ashari, A. Mahmudi, Y.I. Nakhoda, "Camera-based Shooting Simulator Using Color Thresholding Techniques," Proceedings of 3rd International Conference on Instrumentation Control and Automation, pp. 207-211, August 28-30, 2013, Bali, Indonesia.

[5] J.F. Lapointe, G. Godin, "On-Screen Laser Spot Detection for Large Display Interaction," Proceedings of IEEE International Workshop on Haptic Audio Visual Environments and their Applications, October 1-2, 2005, Ottawa, Canada.

[6] R.B. Widodo, W. Chen, T. Matsumaru, "Laser Spotlight Detection and Interpretation of Its Movement Behavior in Laser Pointer Interface," Proceedings of IEEE/SICE International Symposium on System Integration, pp. 780-785, December 16-18, 2012, Fukuoka, Japan.

[7] N.W. Kim, S.J. Lee, B.G. Lee and J.J. Lee, "Vision Based Laser Pointer Interaction for Fexible Screens," Proceedings of the 12th International Conference on Human-computer Interaction: Interaction Platfoms and Techniques, Vol. 4551, 2007, pp. 845–853.

[8] http://www.cmucam.org/projects/cmucam4/

[9] P. Corke, “The Machine Vision Toolbox: A MATLAB Toolbox for vision and vision-based control,” IEEE Robotics and Automation Magazine, Vol. 12, No. 4, pp. 16-25, 2005.

Aryu_Proceeding_2014-2.pdf

ORIGINALITY REPORT

12%	8%	16%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Aryuanto Soetedjo, M. Ibrahim Ashari, Ali Mahmudi, Yusuf Ismail Nakhoda. "Raspberry Pi based laser spot detection", 2014 International Conference on Electrical Engineering and Computer Science (ICEECS), 2014 Publication	7%
2	Soetedjo, Aryuanto, M. Ibrahim Ashari, Ali Mahmudi, and Yusuf Ismail Nakhoda. "Camera-based shooting simulator using color thresholding techniques", 2013 3rd International Conference on Instrumentation Control and Automation (ICA), 2013. Publication	3%
3	thescipub.com Internet Source	2%

Exclude quotes	On	Exclude matches	< 2%
Exclude bibliography	On		