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Automatic Shooting Scoring System Based on Image Processing

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Abstract. Today, many shooting venue that held shooting training used conventional methods to accumulate shooting scores. These conventional methods for shooting training will need more time and resources to do such a task. These paper describes an automatic shooting scoring system based on image processing for live shooting session. A camera is mounted in front of shooting target frame to capture every single shoot image. We use several image processing algorithms such as target ring detection, perspective transform, image subtraction, as well as morphological image processing. Contour detection method is used to perform a perspective transform, obtaining circle diameter and center circle position by using bounding box function by extracting detected contour and bullet hole position.
Our experimental results, show that the accuracy of our method is 91%, based on the experiment by using a tiny circle sticker with a diameter of 7.62mm to simulate as a bullet hole image. We use 10 target sheets which there are 10 bullet hole images using circle sticker in each captured target sheet image.

1. Introduction

Before usage of pistols in 1300, first shooting activity has been held as an archery skill test. The first use of pistols was designed for a war and then it has been used for shooting sport or hunting. In 1477, a rifle is used for shooting sport which has been held in Eichstaat, Bassvaria, where the competition take a distance for about two hundred meters and matchclock is used for each athletes [1]. Nowadays, shooting activity is not only for army or forces but also become a part of national and international competition in several categories and in another side some hunter and hobbyist need a shooting practices for having fun or their self-defense [2]. Nowadays, the development of shooting activity more advance and more varied in terms of the gun especially on the scoring system. Along with the development of technology, shoot scoring system has been developed to automatically scoring system. An automatic scoring system for shooting has been developed in several types of scoring system from acoustic based scoring system, vision based scoring system, or combination of acoustic based scoring and vision based scoring system [3]. One of developing technology in automatic shoot scoring system is vision based automatic scoring system. Vision based scoring system using camera to get information about shooting results of athletes during training session or in a competition. In some cases, the information of an athlete training result is unknown because there is no live monitoring to facilitate the athlete [4] and in another hand, conventional way of scoring system which is operated by human lack of efficiency, system safety, and consumption of time [5]. There are so many researchers has been develop vision based system as an example soccer robot which is use a camera to detect the ball and the gate. In this research, vision based is used to detect each scoring circle inside target sheet and bullet holes position inside the target sheet toward scoring ring. Automatic shoot scoring system is one of a kind system which is needed today to facilitate the olympiad and shooting training session for athlete, hunter or hobbyist. The first background of this research, scoring system in shooting activity still use a conventional method that manually operated by hand which is need more additional time to process and need more human resources as assistant to process score calculation [6]. Second, price of the device for automatic scoring system is not inexpensive, therefore only for about two or three venues who use automatic scoring for training session and olympiad necessity. Hopefully, by applying this automatic scoring system can facilitate and improve the performance of athletes and give a good feedback result to the atheletes [7].

2. The Proposed Method

In this research, developed an automatic shooting scoring system based on image processing by using single camera stationary frame type and from this research the firing mechanism is single shot firing. This paper will describe the system architecture and recognition algorithm of automatic shooting scoring system based on image processing.

2.1. Automatic Shooting Scoring System

Automatic shooting scoring system based on image processing divided into two types based on position of camera which are single camera stationary type and camera on weapon type[8]. Single camera stationary type is a kind of scoring system with camera installed on target frame and for camera on weapon system the camera is placed on the gun. In this experiment, we used the first type of scoring system where the camera installed on the automatic shooting scoring frame. Automatic shooting scoring frame is designed using a lowcost material and it could be upgraded for another modification for training session or olympiad necessity. Automatic shooting scoring frame using 20mm x 20mm aluminium profile to put target sheet on it which has a styrofoam to put the target sheet. Onside scoring frame given a camera holder to put the camera and take a picture of target sheet each shot has been performed. Camera placed onside frame to avoid much backlight from outside to make the image processing more precision. Automatic shooting scoring frame shown in Figure 1.

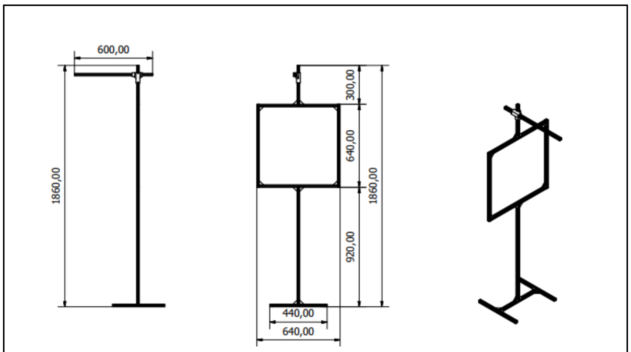


Figure 1. Automatic Shoot Scoring Frame Design

2.2 Automatic Shooting Scoring Hardware Structure and Frame Placement

This automatic shooting scoring system used several hardware to perform an automatic shooting scoring such as microphone sensor module, arduino nano microcontroller, camera, personal computer, and display monitor. Microphone sensor module as an input is used to detect the presence of gunshot sound. Microphone will send data to arduino nano an analog value from the sensor. After the sound of gunshot has been detected from the sensor, the sensor will give an analog value of the sound to arduino nano. The analog value is processed by arduino to recognize the sound of gunshot and converted to digital value. Arduino will give “1” value if gunshot is detected and “0” if there is no gunshot detected from the sensor. Arduino will send a digital value while gunshot is detected to personal computer as a trigger to take picture of target sheet with bullet hole inside using camera. From the captured target sheet image, personal computer will processes the image processing such as image transformation, scoring circle detection, bullet holes detection, and scoring mechanism. Display monitor as an output device to give the atlhetes a realtime information about the result of the shot during shooting session. The placement of automatic shooting scoring frame is placed with a distance from the athletes. There are two sides in this system which are, athlete side and target frame side. Microphone sensor module, arduino nano, personal computer and display monitor is placed on the athlete side otherwise on target frame side consist of a target frame and camera. Placement of automatic shooting scoring frame to athletes position shown in Figure 2 and automatic shooting scoring system gunshot detector shown in figure 3.

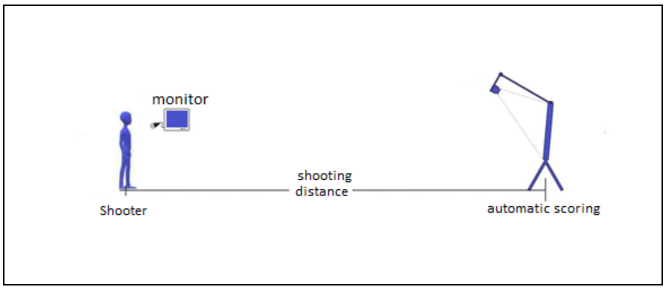


Figure 2. Automatic Shooting Scoring Frame Placement

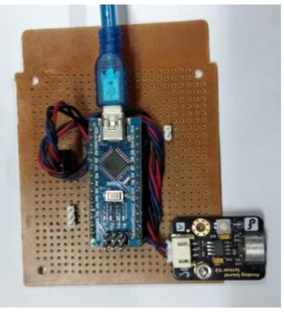


Figure 3. Electronic hardware of gunshot detector

2.3 Automatic Shooting Scoring System Based on Image Processing Architecture

Figure 4 shows the proposed automatic shooting scoring system based on image processing architecture. In the given automatic shooting scoring architecture consists of four main process which are image perspective transformation, scoring circle detection, bullet hole detection, and scoring mechanism. Image perspective transformation is used to transform the distorted image to the steady image in case of placement camera to target make an angle which caused the image distorted. Ring detection block processes the image to obtain each target circle diameter of each score value. Bullet hole detection block processes the image of each shot and classify the center position of bullet holes towards each scoring circle. Scoring mechanism block processes data of each center circle position, diameter value of each scoring circle and the center position of each bullet hole to calculate a score for each shot.

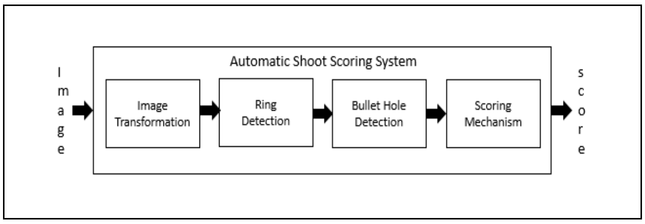


Figure 4. Automatic shooting scoring image processing architecture

2.4 Overall Automatic Shooting Scoring System Architecture
Figure 5 shows the overall automatic shooting scoring system architecture. From the picture can be seen that camera will stream until gunshot is detected from the microphone sensor and arduino will send the personal computer a digital data as a trigger to capture an image of target sheet. Captured target sheet will be processed by using image processing process shown in Figure 4 and extract the target sheet image to obtain a score from each bullet hole. The obtained score will appear in display monitor on the athlete side. The scoring process will stop until maximum shot is reached.

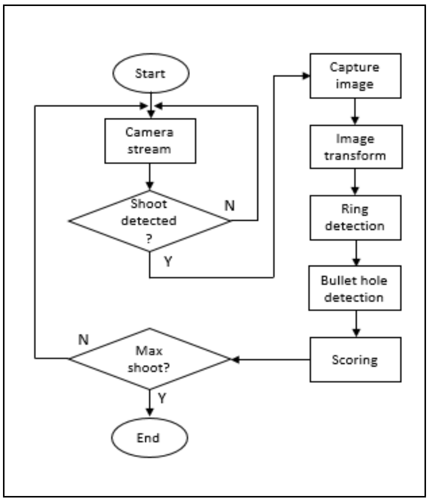


Figure 5. Overall automatic shooting scoring system architecture

2.5 Perspective Transformation of Target Sheet Image
In case the placement of camera is onside the target sheet, it makes a camera to target angle and caused the captured image distorted. The distorted image which induced by camera to target sheet position must be corrected first before extracting quantitative measurements[5]. In this process given a perspective transformation method which is the function of perspective transformation is to correct the distorted image [9] and perspective transformation change a perspective projection to parallel projection [10] with a perspective transformation formula shows as follows:

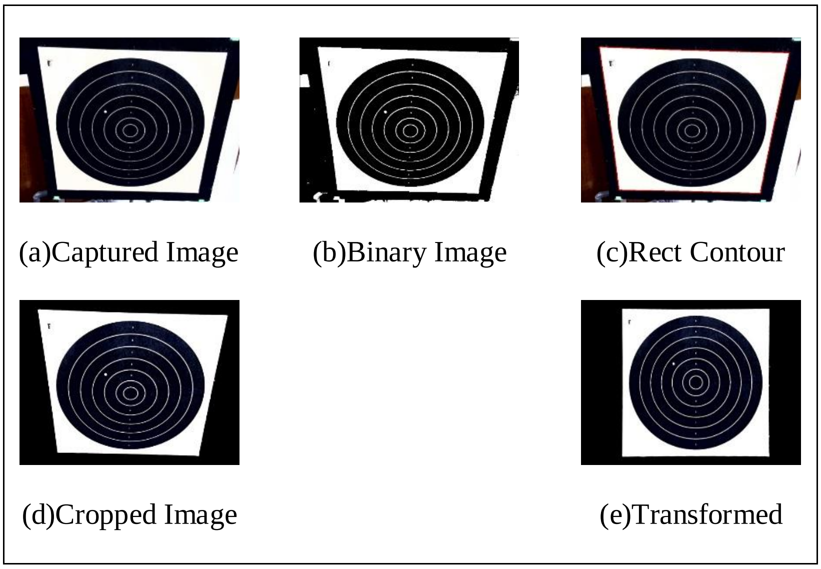
$$[x', y', w'] = [u', v', w'] \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \quad (1)$$

Wherein, (u, v) as the original coordinates of an image and (x, y) as obtained coordinates after transform (x, y), and $x = x'/w, y = y'/w'$ where x and y can be obtained by calculation below.

$$x = \frac{a_{11}u + a_{21}v + a_{31}}{a_{13}u + a_{23}v + a_{33}} \quad (2)$$

$$y = \frac{a_{12}u + a_{22}v + a_{32}}{a_{13}u + a_{23}v + a_{33}} \quad (3)$$

From the matrix shows that $\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$ represent a linear transformation process, while $[a_{31} \quad a_{32}]$ for translational process, and $[a_{13} \quad a_{23}]^T$ is for perspective transformation process[11]. Figure 6 shows the perspective transformation process of a distorted target sheet image.



(a)Captured Image (b)Binary Image (c)Rect Contour

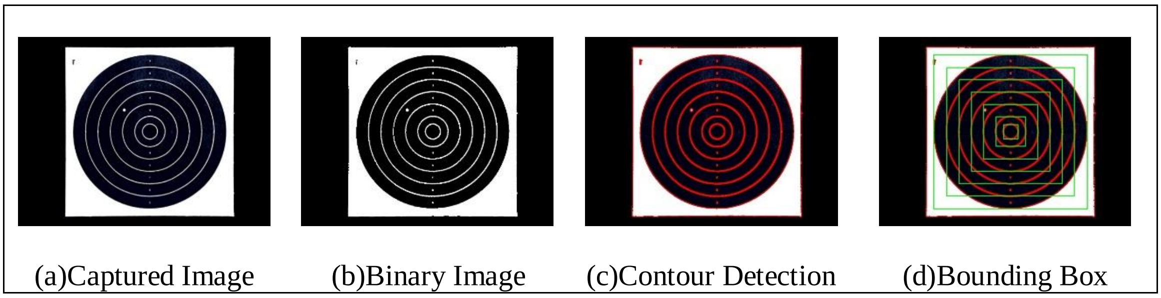
(d)Cropped Image (e)Transformed

Figure 6. Perspective Transformation Process of Distorted Image

Figure 6(a) shows that the input image has been captured and converted to binary image in Figure 6(b) by performing grayscaling and thresholding process. After obtained a binary image of target sheet, the next process is obtaining the rectangle contour of target sheet image that has been applied in Figure 6(c) using contour detection method. Cropped image has been obtained in Figure 6(d) and the last process is performed a perspective transformation that can be seen in Figure 6(e).

2.6 Circle Detection, Circle Diameter and Center Circle Achievement

After perspective transformation of target sheet image obtained, the next process is to detect scoring circle, obtain the circle diameter and center position of scoring ring by using contour detection method. Circle diameter and center position of each circle can be obtained by applying bounding box function to extract the height and width value from each detected circle contour and from the bounding box process obtained the x axis and y axis value that can be used as a diameter of each ring by choosing an axis as diamter parameter. Center position of scoring ring can be obtained by calculate the x and y axis value which is obtained from bounding box process. For each x and y axis is divided by two and will given the center position of circle in x and y coordinate. Diameter value for each scoring ring will be saved to perform scoring calculation process for each detected bullet holes inside target sheet. The process of ring detection shown in Figure 7.

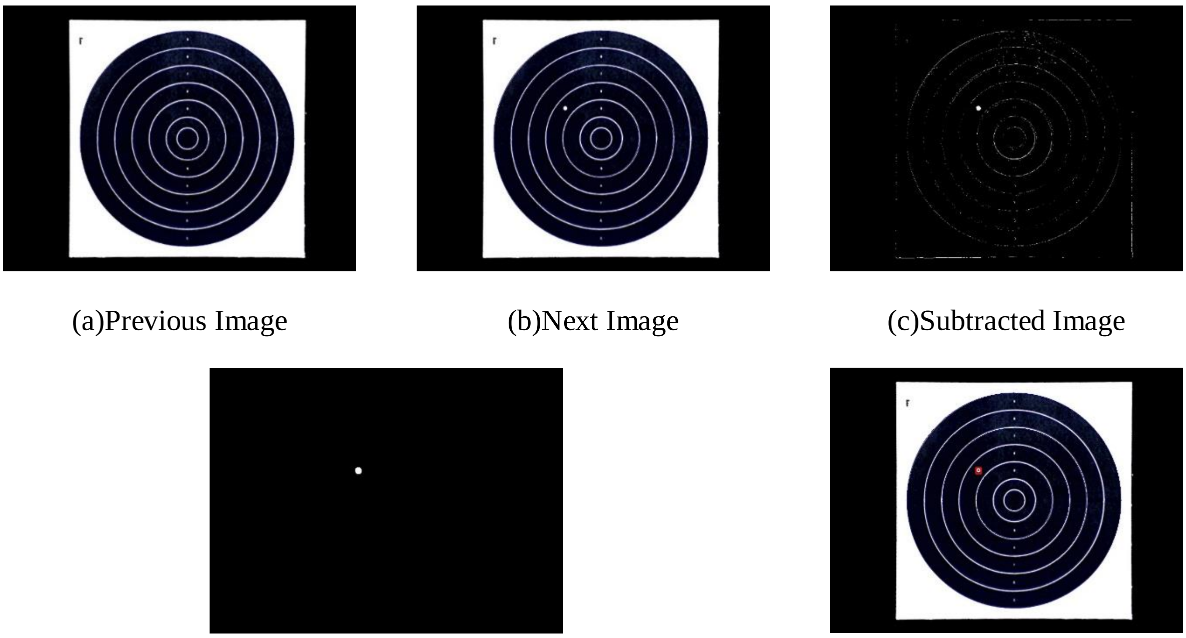


(a)Captured Image (b)Binary Image (c)Contour Detection (d)Bounding Box

Figure 7. Ring detection process and diameter achievement

2.7 Bullet Holes Detection

Method that used in bullet hole detection process is background subtraction where background subraction is a simple method, safe and give good result in realtime processing [12]. Background subtraction method is suitable with this automatic shooting scoring system which is used to extract the target sheet image with bullet hole inside the target. In this process, the difference between previous image an current image can be solved by using image subtraction method [13]. In this research, detecting bullet hole inside the target sheet using image subtraction method to obtain the position of each bullet hole in each captured frame by comparing the previous image with the current image that has been taken. Every frame of an image taken by camera for each shot will be saved as a comparison image to apply image subtraction process and compared with the new frame with a new bullet hole inside the target sheet. After bullet hole detection process is finished by using image subtraction method, the next process is to extract the bullet hole by using contour detection to obtain contour of bullet hole. Center position of bullet hole can be obtained by using bounding box function from openCV to extract the bullet hole contour by giving a rectangle boundary. From this process obtained the center position of bullet hole in x and y coordinate from extracting the width and height of contour where the center position of bullet hole will be used for scoring process in the scoring mehanism. In this automatic shooting scoring system, the previous image of target sheet that has been extracted is overwriten with the new image and this cycle will occur until maximum shot reached. From the following process, image subtraction method is a good method to detect bullet holes from each shot inside target sheet, but in case the sensitivity of the image subtraction method, it easy to make noises because the change of external condition in example light and another unwanted even can influenced the image subtraction process[14]. Some noises occured in image subtraction process because the sensitiveness of image subtraction method and make the scoring process not precision even image morphological is apllied to reduce the noises by aplying erotion and dilation process. Figure 8 shows the process of bullet hole detection inside target sheet.



(a)Previous Image (b)Next Image (c)Subtracted Image

(d)After Morphological Process (e)Detected Bullet Hole

Figure 8. Bullet Hole Detection Process

2.8 Scoring Mechanism

Center coordinate of inner circle position, ring diameter and bullet holes position which obtained based on image subtraction, the following process is scoring mechanism for each bullet hole inside target sheet. Scoring process by using phytagoras theoreme which used to calculate distance between bullet hole center to target sheet center circle by calculate the distance from x and y axis. After distance of bullet hole position to center circle is obtained, next process is comparing distance value which is obtained by phytagoras theoreme with radius of each ring that is obtained by ring detection before. Figure 11 is example of bullet hole relative position to center circle for scoring mechanism.

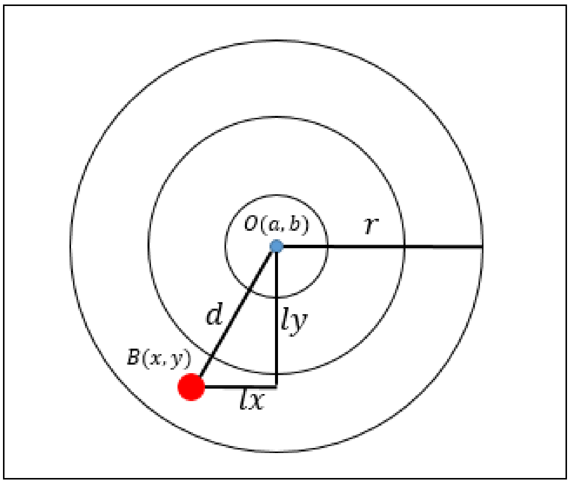


Figure 9. Scoring calculation using phytagoras theorem

Scoring calculation is processes to obtain distance center circle of the target to center of bullet hole by using phytagoras theorem to classify the position of bullet holes and make a score, thus:

$$\boldsymbol{d^2 = \sqrt{(x-a)^2 + (y-b)^2}} \qquad (4)$$

Where :
d : distance of bullet hole to center circle
lx : bullet hole distance to center circle in x axis
ly : bullet hole distance to center circle in y axis
x : bullet hole center position in x coordinate
y : bullet hole center position in x coordinate
a : bullet hole center position in x coordinate
b : bullet hole center position in x coordinate

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3. Experiment result

This part presents result of experiment by 25m air rifle with radius value obtained from bounding boxes process for each ring where the radius value is shown in Table 1. From ring detection process, there are some different radius value for ten different captured image from several ring inside target sheet by more or less 2 pixel but still satisfy the scoring mechanism to make a score.

Table 1. Scoring ring radius value from inner circle to outer circle from each captured image

Picture	*Radius value from inner scoring ring to outer scoring ring (Ring 1 ~ Ring 7) in pixel*						
	Ring 1	*Ring 2*	*Ring 3*	*Ring 4*	*Ring 5*	*Ring 6*	*Ring 7*
	Score 11	*Score 10*	*Score 9*	*Score 8*	*Score 7*	*Score 6*	*Score 5*
1	24	48	87	127	166	206	247
2	24	48	87	127	166	206	247
3	24	48	87	127	166	206	247
4	24	48	87	127	166	205	247
5	23	48	87	126	166	205	247
6	24	48	87	126	166	206	247
7	24	48	87	125	166	205	246
8	23	48	87	126	166	205	246
9	23	48	87	126	166	205	247
10	23	48	87	125	166	205	247

For the automatic shoot scoring experiment, an experiment has been tested by using a circle sticker as bullet holes simulation. The experiment tested by using 10 (ten) circle sticker for each target sheet give a result as shown in table 2.

Table 2. Automatic scoring result using circle sticker simulation

Image	*Shooting attempt in each target sheet*									
Sheet	*1st*	*2nd*	*3rd*	*4th*	*5th*	*6th*	*7th*	*8th*	*9th*	*10th*
1	8	7	11	10	8	5	6	x	9	7
2	x	x	9	x	x	x	8	8	x	9
3	8	10	9	9	8	9	8	11	x	x
4	6	7	8	9	10	9	9	11	11	11
5	6	7	10	10	11	9	10	9	5	10
6	10	10	9	7	8	8	9	8	9	11
7	7	9	11	11	11	10	8	9	9	9
8	9	5	7	8	10	9	10	11	10	8
9	10	10	11	9	10	11	9	10	9	9
10	5	8	9	10	11	9	8	10	8	10

4. Conclusion and discussion

As can be seen from the experiment results above, our automatic shooting scoring system can give a good result for scoring calculation, which are 91% accuration with 9 errors caused. We use several image processing methods especially perspective transform combined by contour detection and image subraction. Eventhough there is a weakness in image subtraction process, which is the noise resulted from this procedure cause errors in bullet hole detection. In the future, we try to minimzed this error by using other methods.

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