The Development and Implementation of a Smartphone Based Archery Analysis System

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***Abstract*—In this paper, we propose a smartphone based system for analyzing archery images. The front-end of our proposed system is a smartphone APP. The user can use the APP to take a photo of archery target and browse the analysis results. The back-end of our proposed system is responsible for detecting arrows in the archery image and determine the resulting score. The main advantage of our APP as opposed to the existing archery APPs is that it can automatically determine archery score without manual input. We have conducted experiments using images provided by the archery team of National Chung Cheng University. The results demonstrate the potential of using our proposed system in archery training.**

***Index Terms*—smartphone application, object detection, automatic archery scoring, computer-aided archery training**

I. Introduction

The history of archery extends back to the ancient times. It is still getting more and more popular around the world. During an archery game, an archer stands a distance from a target and shoots arrows toward the target center. An archery target consists of 10 concentric rings with different points. The archer receives 10 points for hitting the innermost ring and 1 point for hitting the outermost ring. During an archery training or competition, it is a quite time consuming task to determine the score of each arrow based on visual inspection. It would be highly desirable to have an automatic scoring system for archery. This system can also produce many training statistics and keep detailed training records for each archer. It would be helpful for coach to analyze the strength and weakness of his or her archery athletes.

There are several existing methods for automatic archery scoring in the literature [1]–[4]. The earlier approaches [1], [2] are not based on mobile devices, hence their practical usability is limited. With the advance of technology, recent works [3], [4] began to leverage the advantages of mobile devices. Inspired that, we develop a smartphone based system for analyzing archery image. In our proposed system, we first utilize YOLOv4 [5] to detect arrows in an archery target image. In order to handle the target images captured from various angles, we have developed a method to find the minimum enclosing ellipses of each score region. Thus, we can perform scoring based on which two ellipses an arrow falls between. Finally, we develop a smartphone APP as the user interface. The APP allows users to record the coordinates of arrows, accuracy and precision of each training session.

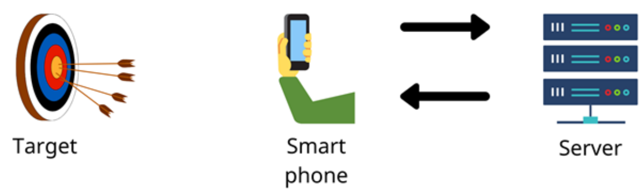


Fig. 1. The architecture of our proposed smartphone-based archery analysis system.

The rest of this paper is organized as follows. In Section II, we introduce our proposed system for archery image analysis. In Section III, we report our experimental results on detection accuracy and scoring accuracy. Finally, we make concluding remarks in Section IV.

II. Proposed Method

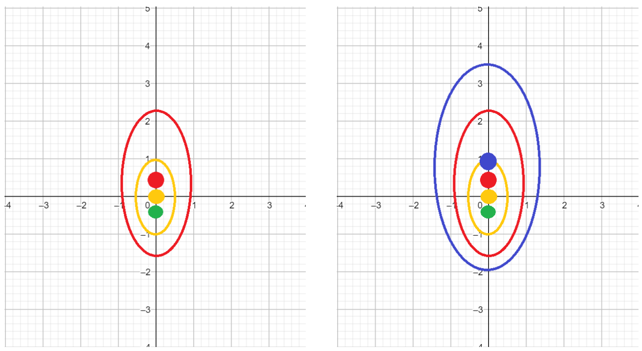
In this section, we introduce our proposed smartphone-based archery analysis system. Figure 1 shows the our system architecture. Briefly speaking, we first take a picture of an archery target using a smartphone. Then, the smartphone will send this picture to a server. The server can identify where the arrows hit the target by using a state-of-the-art objection detection technique. After finding the landing points of each arrow, we can calculate their scores and statistics for athletic training. Finally, the server will send these information back to the smartphone for display. We describe the implementation details of our proposed system in the following subsections.

A. Arrow Detection

We utilize objection detection technique to locate arrows in an archery target image. Here, we use YOLOv4 [5] as our object detector. In particular, we perform transfer learning on the pre-trained YOLOv4 model so that it learns how to detect arrows on an archery target. Since we only have about 200 training images, we use data augmentation to generate more training samples. Thus, we have generated 12,000 images for fine-tunning the YOLOv4 model.

B. Archery Score Calculation

For the ease of explanation, we use a synthetic example to illustrate how we calculate archery score. Suppose the



(a) (b)

Fig. 2. (a) The the minimum enclosing ellipses of yellow and red regions are found by the OpenCV fitEllipse function. (b) The the minimum enclosing ellipses of blue region and its center point are determined by our method.

yellow and red ellipses in Figure 2(a) represent the minimum enclosing ellipses of yellow and red regions in a non-frontal view target image. We can use the center points of these two ellipses (the yellow and red points) to determine the center point of the original concentric circles (the green point). More specifically, let (u_1, v_1) and (u_2, v_2) denote the center points of yellow and red ellipses, respectively. The center point (u_3, v_3) of the original concentric circles is determined by

$$u_3 = \frac{R^2}{R^2 - r^2} u_2 - \frac{r^2}{R^2 - r^2} u_1 \quad (1)$$

$$v_3 = \frac{R^2}{R^2 - r^2} v_2 - \frac{r^2}{R^2 - r^2} v_1 \quad (2)$$

where R denotes the radius of the original red circle and r denotes the radius of the original yellow circle.

So, we use this method to obtain the minimum enclosing ellipses of each score region. After knowing the minimum enclosing ellipses of each score region, we can determine the score of an arrow according to which two ellipses it falls between.

C. User Interface

We have developed a smartphone APP for our archery analysis system. Our APP allows users to login to their own accounts to add, modify, or delete archery training data. The users can also view their historical training data or export the whole training data to an excel file. Our system can record the coordinates of arrows, accuracy and precision of each training session.

III. Experimental Results

We have conducted experiments using the archery images provided by the archery team of National Chung Cheng University, Taiwan. We first evaluate the accuracy of arrow detection. Table I shows the detection accuracies and number of false detection of 11 test images. The detection rate is calculated as follows:

$$\text{Detection Rate} = \frac{\text{Number of correctly detected arrows}}{\text{Number of total arrows}} \quad (3)$$

TABLE I
Accuracy of Arrow Detection

	Detection Rate	Number of False Detection
Test image 1	10/12 = 83%	1
Test image 2	8/10 = 80%	0
Test image 3	6/6 = 100%	0
Test image 4	4/6 = 67%	0
Test image 5	4/6 = 67%	0
Test image 6	11/12 = 92%	0
Test image 7	10/11 = 91%	0
Test image 8	5/6 = 83%	1
Test image 9	8/11 = 73%	2
Test image 10	3/6 = 50%	0
Test image 11	6/11 = 55%	1
Average	75/97 = 77%	0.45

For instance, there are totally 12 arrows in the test image 1. Among the 12 arrows, only 10 of them are detected by the YOLOv4 algorithm. In other words, 2 of them are missed by the detector. Thus, the detection rate is $10/12 = 83.33\%$ and the miss rate is $2/12 = 16.67\%$. In our experimental results, we observe that there are usually one or two missed arrows in one test image. The root cause of missed detections is largely due to occlusion between arrows. Or, two arrows hit almost the same spot on the target.

In addition to detection rate, We also report number of false detections in Table I. Among 11 test images, seven images do not have any false detection, three images have one false detection, and one image have two false detections. So, our detector tends to have more missed detections than false detections. This is the preferred setting as suggested by the archery team.

IV. Conclusion

In this research work, we develop a smartphone based system for analyzing archery target images. Our system can automatically detect arrows in an archery target image and performing scoring. This is our first step toward computer-aided archery training. It will require close collaboration with archery athlete, coach, or even or sport psychologist to make our APP more useful in practical scenarios. The ultimate goal is to help athletes understand their strength and weakness so that they can have better performance in archery competition.

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