Performance Evaluation by Image Processing Techniques in Archery – A Case Study

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Abstract: Archers find postural sway, unforced changes and irregular displacement that negatively correlate to their technical level and hence their performance. Using image processing, the biomechanics of the various joints angles during the different stages of shooting can be used to correlate to an archer's performance. The study presented, evaluates the biomechanical analysis of an international gold medalist archer using image processing techniques. The subject in this study, shot arrows in archery shooting range while a video camera captured the body posture. Furthermore, the joint angles were studied at different phases of shooting and all the parameters were correlated with the archer's performance in order to propose the correct shooting technique. By studying the motion analysis of repetitive different shots a standard model for better performance has been proposed for performance enhancement.

Keywords: Archery, biomechanics, image processing, motion analysis.

I. INTRODUCTION

Archery is a static non-contact sport, in which arrows are shot forward with a bow to the target during shooting [1]. It is that sport that expects the archers to possess muscular strength, high level postural stability and upper body endurance [2]. An archer pushes the bow with an extended arm, which is statically held in the direction of the target, while the other arm exerts a dynamic pulling of the bowstring from the beginning of the drawing phase, until the release is dynamically executed [3]. For determining the success of every shot, the postural stability is the most crucial variable. The release phase must be well balanced and highly reproducible to achieve commendable results in a competition [4]. High performance shooting in archery is defined as the ability to shoot an arrow at a given target with accuracy [5]. Recurve archery is an Olympic sport, which requires extreme precision, upper body strength and endurance. Many variables like pre- and post-arrow release, draw force line, flight time, arrow length, clicker reaction time, shoulder muscle tremors at full draw in relation to clicker reaction time, effect of upper body strength interventions all affect the scoring outcome [6].

A. Archery performance evaluation

Performance in archery is designated based on the sum of the scores of the arrows shot by an athlete on the target. Performance of the athlete is governed by various factors including environmental conditions, fatigue, and the athlete's technique, in addition to the effects of the materials that determine the behavior of the bow and the arrow. The positioning of the shot arrows on the target board is considered to imply important information to assess the targeting performance [7]. Archers find postural sway, unforced changes and irregular displacement that negatively correlate to their high performance [2]. In archery it is important that the archer is able to hold the pulling force of the bow isometrically at release. The archer is required to stand still for quite a long period of time and maintain the required posture and balance during the shooting process. Posture stability, clicker reaction time and bow draw force are most important determinants in high performance elite recurve archery [6]. Although usually consistent for each archer, the aiming time usually varies with the quality of the

arrow shot. While in some cases the aiming time may also be increased as the quality of the arrow decreased [8].

The angle and position of the draw-arm elbow play an important role in subjecting force to the shoulder. Therefore, the position of the elbow should be aligned with the line of force, i.e. having the distance of the shoulder line and line of force at the shortest. This biomechanical parameter, the line of force is called the Draw Force Line (DFL). In addition, the release phase must be well-balanced and highly reproducible to achieve commendable results in an archery competition [9].

B. Image Analysis

The scope of image processing algorithms are fairly expansive, ranging from automatically extracting and delineating regions of interest such as in the case of image segmentation, to improving the perceived quality of an image, by means of image enhancement. A major limitation in the design of image processing algorithms lies in the difficulty in demonstrating that algorithms work to an acceptable measure of performance [10]. Lately methodology is based on color features and therefore several color image processing techniques such as background subtraction, blob color definition (RGB and HSL color spaces) and color blob manipulation are employed in order to detect the players. In order to have a clean interface and proper functioning for working with the image database the OpenCV library was used [11]. Nowadays there is the tendency to apply techniques from different categories in order to achieve better results. A good example of this tendency is the JSEG algorithm which initially clusters colors into several representative classes, afterwards replaces each pixel by their corresponding color class label and at the end employs a region growing process directly to the class map in order to identify homogeneous regions [12]. On the other hand, video cameras used in computer-vision-based approaches enable unobtrusive recovery of individuals' positions and trajectories [13]. On videos, contrary to static images by camera, besides the physical (x and y coordinates) and color information, the time component can also be studied. Using this property it is possible to segment images based on motion-along-time. There are two main approaches to perform this task: background subtraction and optical flow [14].

The purpose of this study was to evaluate the biomechanical analysis of an international archer using image/video processing techniques using color detection to find pixel coordinates for both pre- and post-arrow release, draw force line and their impact on the performance (score). Furthermore, the joint angles during aiming and after releasing the arrow were also studied using vector algebra on python platform using OpenCV libraries.

II. METHODOLOGY

A. Subject

An International Gold Medalist archer was selected as the subject for this research. The elite athlete was instructed to shoot at a 70m distance target at the Archery Shooting Arena of the SMS stadium, Jaipur, Rajasthan, India. The subject selected is a right-handed recurve bow archer, aged 23 years. His physical characteristics are; height - 176 cm, body weight - 89 kg and height of the sternal head - 152 cm from the ground level. Since the measurement experiments were run in continuous fashion, some of the equipment was installed on the subject’s body, namely the reflective markers.

The subject was asked to perform shoots for 6 rounds, a total of 36 arrows. The anchor time is the position where the drawing hand makes contact with the face till the arrow clearance. The time taken to shoot an arrow was taken by a qualified coach using stop watch (Nivia; 1/100 of a second).

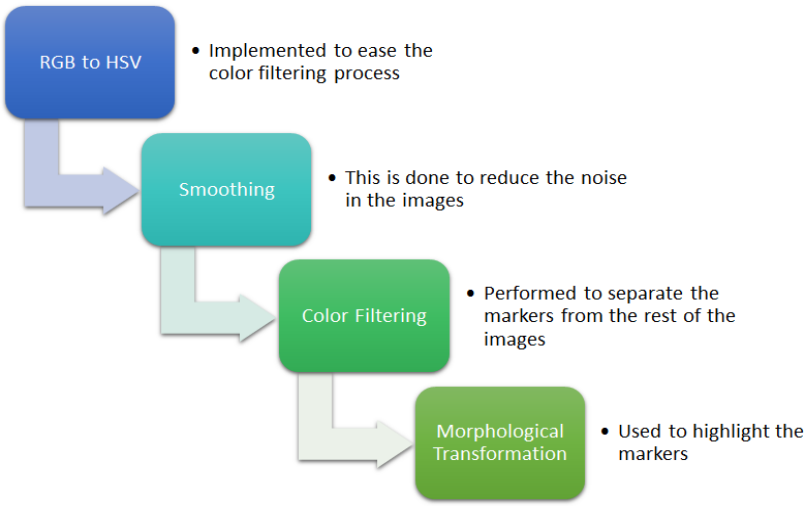


Fig 1. Image processing method for finding out the markers

B. Videography and image processing

The camera (Fuji X-S1, 12 megapixels) was fixed at a distance of 155 cm and a height of 152 cm, from the archer and the ground respectively to ensure that the subject's sagittal view was in the correct position for drawing the bow, aiming and releasing the arrows. The camera was synchronized and set to 29 frames/s. In order to measure the draw force line, 7 reflective markers were placed on the subject's wrists, elbows, shoulders and sternal head. Then, image processing is done on Python platform using OpenCV libraries. The video being recorded by the camera is converted into frames, for the ease of analysis. Image processing methods are applied on the frames to filter out the markers. The process of filtering out the markers is explained in Fig 1.

These image processing methods are applied for a sample of 6 arrows (last round) out of 36 arrows shot. Draw force line angular deviation in case of Anchor Position and Release Point was calculated. As can be seen in the Fig 2, the markers are highlighted in the images and their coordinate positions are calculated using the python platform. The coordinates found are then integrated into vector algebra, to find out the resulting draw force vector. The angle between this vector and the Draw Force Line (DFL) gives the deviation in the anchor position. Similarly, the same has been done for the release point.

III. Results and Discussion

The findings of this study were based on the biomechanical parameters studied on the subject and the results of the image processing method as described in the methodology. The elite athlete's shooting performance was measured by his shooting scores at a 70m distance target. The shooting scores ranged from 8 to highest score, 10 or the bulls eye. The continuous shooting of the highest score, 10, or the bull's eye depicted the high skill of the elite athlete. The mean score in the present study was 9.50 ± 0.84 (Table 1). To determine the Draw force line angle (DFL) for the anchor position and the release angle point, image processing was performed as mentioned in the methodology using color detection of the reflective markers to find pixel coordinates on X and Y axis and then vector algebra was used to calculate the required anchor angle α, and release angle β, on python platform using OpenCV libraries. The DFL angle in case of Anchor Position (AP) and Release Point (RP) angle after shooting was determined for all 6 shots (Table 1). The mean and standard deviation were calculated as Anchor Position angle (2.76 ± 0.59), Release Point angle (32.43 ± 3.28) and Anchor Time taken to shoot (3.92 ± 1.31).

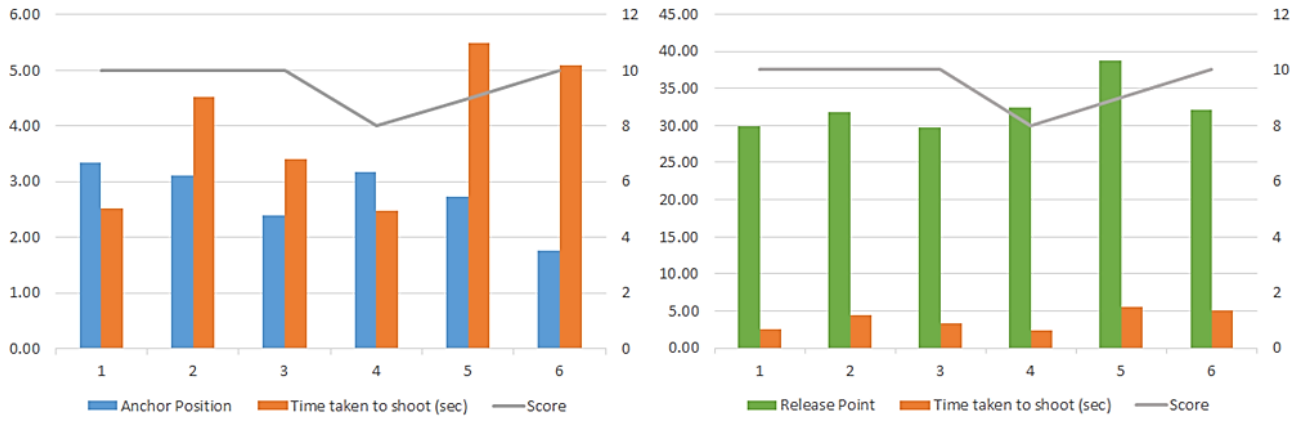
TABLE 1. INITIAL ATTITUDE VALUES

Arrow No.	*Anchor Position (α)*	*Release Point (β)*	*Anchor Time taken to shoot (sec)*	*Score*
1	3.34	29.83	2.53	10
2	3.12	31.84	4.53	10
3	2.4	29.74	3.4	10
4	3.18	32.46	2.47	8
5	2.73	38.69	5.5	9
6	1.77	32.03	5.09	10
Mean	2.76	32.43	3.92	9.50
SD	0.59	3.28	1.31	0.84

The point of origin of DFL is the wrist of the bow hand, which acts as a reference point to determine the angular deviation to the elbow of the draw hand as shown in Fig 2(a). A blue line was drawn between each joint with yellow marker. The right elbow is not found in DFL and is shown by red dotted line, which is common in Recurve archer [15]. Ideally, the elbow should be within the DFL in order to reduce the muscle fatigue as well as to prevent injury [16]. However, in case of our subject who is an elite athlete, this angle size is still considered acceptable as scoring rate is very high, where his body is able to adjust. The results shown in Fig 3(a) illustrate that the DFL pattern, with just a slight angle out. Therefore, we can assume that he is an experienced archer.

(a) (b)

Fig 2. Vector calculation at (a) Anchor Position (b) Release Point



(a) (b)

Fig 3. Deviation angles as calculated by imaging processing (a) at Anchor Position (b) after Release Point; in the figure the primary y-axis is the degree measure of anchor position and release point respectively and the time taken to shoot, the secondary y-axis is the score for the respective arrow marked by the x-axis.

The average release point angle is found as 32.43 ± 3.28 degree shown in Fig 2(b). In the biomechanics of shooting there are three phases involved in this result; setting the bow, aiming and releasing the arrow. It is found that the aiming time is more during the 5th and 6th shoot might be due to fatigue in the arms, but the 5th release angle is found to be more deviated than the average release angle as given in Fig 3(b).

IV. Conclusion

The biomechanical parameters selected in this study clearly affect the archer's performance. The more the stabilization of DFL angle and the release angle, the better will be the shooting score. The wrong drawing technique will create muscle fatigue and also cause injury to the archer. In order to get a good result, stabilization of DFL is crucial, which will reduce the vibration of the body. For better performance image processing technique shall be used for better scientific coaching and training. For future study, archers with different levels of experience and age groups of both sexes can be taken up as the prospective subjects.

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