Intelligent System for the Reduction of Injuries in Archery

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Abstract. Archery is one of these sports in which the athletes repeat the same body postures over and over again. This means that tiny wrong habits could cause serious long-term health injuries. Consequently, learning a correct shooting technique is very important for both beginner archers and elite athletes. In this work, we present a system that uses machine learning to automatically detect anomalous postures and return to the archer a shooting score, that works by giving the archer a feedback on his own body configuration. We use a neural network to analyze images of archers during the firing and return the place of their different body joints. With this information, the system can detect wrong postures which might lead to injuries. This feedback is very important to the archer when learning the shooting technique. In addition, the system is not intrusive for the archer, so she/he can fire arrows freely. Preliminary results show the usefulness of the system, which is able to detect 4 spine misalignment and 4 raised elbow analyzing only 9 shots.

Keywords: Improved sports performance · Injury reduction · Artificial intelligence · Machine learning · Body posture analysis

1 Introduction

The regular practise of sport provides great benefits to our physical and mental health [7], and makes us feel better. However, training improperly or incorrectly might lead us to injuries. Therefore, it is important to have a correct body posture when practicing sports in order to reduce the injuries and pain in specific parts of our body.

In sports such as archery, the sportswomen/sportsmen perform many repetitions of the same steps: Stance, Nocking the arrow, String hand and grip, Body pre-setting, Raising the bow, Pre-draw, Draw, Aiming, Release, and Follow-through. Therefore, bad posture in any of these steps can lead to a future injury [10]. For that reason, it is recommended that a specialised trainer supervises the archer's training to correct possible bad postures before they are becoming injuries, such as: tendonitis, bursitis, or epicondylitis.

The required supervision by a specialised trainer is not always possible, so then beginner archers are especially exposed to injuries. To avoid these harm

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injuries, we propose a system based on new advances in artificial intelligence which can aid athletes, specifically archers, to improve their performance and avoid injuries.

The main contribution of this article is a software system called ATILA (Archery Training through Improvement, Learning and Analysis) that is capable of analyzing the body posture of the archer and detect incorrect positions. The objective of the software system is twofold: the reduction of injuries in novel archers and the increase of the performance as a consequence of a good body posture.

In this article, there are other contributions that we want to mention:

- The evaluation of a shot has been done using a neural network which can extract the joints of the body from images, both pictures and videos.
- An experiment has been performed to evaluate the proposed system.
- Preliminary results show that the system/methodology will reduce the injuries of novel archers.

The reminder of this paper is organized as follows: Sect. 2 presents related work on improving archery performance and a brief base on archery. Section 3 describes the different parts of our system. Section 4 presents our experimental setup. Section 5 provides some preliminary results of our work. Finally, Sect. 6 present the conclusions of the work and the next steps of the research and development.

2 Background and Related Work

People commonly associate archery with the type of archery performed at the Olympics. But, this is only one of the forms of competition that exist in archery. We can classify the competitions according to different criteria:

- Type of bow
- Place of shooting
- Type of target.

There are other criteria for classifying archery modalities such as: shooting styles (Olympic and instinctive) and more specific competitions such as traditional archery, historical recreations, etc. All of these different tournaments allow us to explore different aspects of the archer's skill and body capabilities [6].

Each type of archery has different characteristics in terms of materials and shapes. However, what the archery has in common (except for slight variations) are the different phases through which the archer goes to fire an arrow [3]. In general, the process of shooting an arrow is divided into the following phases:

1. Stance: preparation of body posture.
2. Nocking the arrow: placing the arrow on the rope.
3. String Hand and Grip: initial rope grip and bow.
4. Body Pre-setting: establishment of the body posture with the prepared bow.

5. Raising the bow: elevation of the bow to face the target.
6. Pre-draw: pre-tensioning of the string (beginning of muscular tension).
7. Draw: tensioning of the rope from the raised position to the aiming position.
8. Aiming: the main shooting phase. Static position in which the mark is targeted. This will be the first stage that we will improve with our system.
9. Release: release of the rope. The arrow is fired.
10. Follow-through: follow the arrow with the eyes keeping the body posture.

In order to learn these phases correctly and safely, different approaches have been investigated. Different gadgets can be added to the arch to improve performance [2,13]. The problem with these solutions is that they imply certain handicaps for the archer: greater weight in the bow, mobility limitations, high cost, etc. From the point of view of the coaches, several works have been developed in sports sciences. Some researchers have tried to catalogue the different aspects of the learning process [4], while others have proposed new methods of training [8]. Both ideas are based on the need to have a monitor overseeing the evolution of the beginning archer. However, it would be interesting to be able to get feedback from a coach without having to have one available every time he or she takes a shot.

Artificial intelligence and machine learning have been very useful in different domains. In this work, we are interested in the use of artificial intelligence and machine learning in the Sports domain [11], and in particular in archery [5,9]. The utilisation of artificial intelligence in the sport of archery is still in its infancy [12], though there are already interesting studies such as the one carried out in [5]. In that work, Chang et al. applied clustering techniques to different physical magnitudes of athletes, e.g. arm tension or bow power. Using the collected data, they compared talented athletes with those who have a fairer performance. However, obtaining some kind of personal data can be intrusive for the archer because you need specialized measuring instruments. Moreover, by not taking the position into account, it is not possible to know how long the archer's useful life will be.

3 Proposed Training System: ATILA

Injuries can shorten or even interrupt the athlete's career and cause health problems. Identifying bad habits in the body posture of athletes can greatly reduce the number of injuries during their career and therefore have a higher and more continuous performance. In the particular case of archery, a series of steps are repeated continuously to perform the arrow shots. Going further, the archers seek replicability of the shot. Consequently, it is noteworthy that making some incorrect posture in some of the phases as custom, causes that part of the body suffers for all the repetitions made.

Intending to avoid injuries in archers, we propose ATILA, a software system which collects images of the archer and detects bad habits, communicating them so that the archer can make appropriate posture corrections.

This system focuses mainly on beginner archers but is equally useful for refining technique in more experienced archers. Our system consists of the following phases: image acquisition, calculation of the position of the body joints, analysis of the relative position, and evaluation of the shot. Figure 1 shows a brief schematic of ATILA. Next, we will describe each phase in more detail.

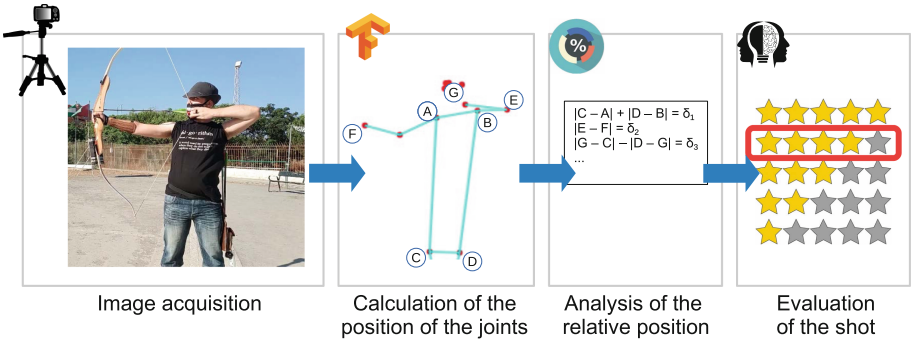


Fig. 1. System overview.

3.1 Image Acquisition

Not be intrusive is a mandatory requirement of our system because we do not want to disturb the archer while shoots arrows. The quality of current cameras (professional or even smartphones) enables us to work with high-quality photos and videos. Besides, we use a tripod located only one meter away from the archer (for the stability of the images), which along with the wide-angle of a smartphone's camera is enough to have a complete image of the archer and bow.

3.2 Calculation of the Position of the Joints

The computation of the body joints is a key phase of ATILA. For this task, we use a neural network built through Tensorflow [1]. The neural network allows, given an image, to detect the different joints of the body and parts of the face (eyes, nose, mouth and ears) returning their coordinates. It also provides a level of precision in each area. In this work, it is of special interest the relative positions between the different parts of the body, to obtain a correct alignment of the posture. Mainly, we will focus on the points from the hip to the eyes, since in the upper part of the body are the main areas of interest.

3.3 Analysis of the Relative Position

Each person has a different height and complexion. To make our system more robust to the specific characteristics of different archers, we work with the relative

position of the different parts of the body. The connection between the position of these parts of the archer's body allows us to calculate a series of indicators of the quality of the shot. These indicators allow us to detect if the elbow is not correctly aligned with the hand, the hips and head are not centred, or the shoulders are excessively raised, to name a few. Table 1 describes some of the incorrect body poses ATILA can detect by using the position of a subset of joints or body parts. More postures should be taken into account, but these are the main causes of injuries during the aiming phase. Besides, there are body postures which are not harmful but imply bad performance in the shot. Then, our system would be able to detect poses that are detrimental to the performance of the shot, but that is not the focus of this work.

Table 1. Incorrect body posture and effects on the archer detected by our system.

Incorrect posture	Detection	Firing effect	Injury
Misaligned spine	Shoulders misaligned with respect to the hips	Shot too high or too low	Back problems
Elbow, of the arm that holding the rope, too high	Wrist and shoulder misalignment	Inaccurate shooting	Injuries to the wrist, shoulders and muscles of the arm and forearm
Neck forward	Eyes, nose, and ear misaligned with the spine	Loss of power in the shot	Strikes on the head with the rope, contractures in the neck
Arm of the bow shrunk	Difference between the detected dimensions of both arms	Lack of power by not achieving a complete opening of arms	Muscle fatigue in arms and forearms
Misalignment of the arms	Elbows, wrists and shoulders misaligned vertically	Inaccurate shooting	Damage to different muscle groups, shoulders, arms and back

3.4 Evaluation of the Shot

According to the information obtained in the previous step, it is possible to give a score of the quality of the shot. Two types of "good shots" can be distinguished: high precision and not harmful. Advanced athletes, who have already fully learned the right postures, will be looking for performance improvements. On the other hand, beginner archers must develop a shooting technique that allows them to have a long way as healthy athletes. Both types of shots are closely related. However, it is less relevant to hit the mark on an initial stage of learning. Our system will allow you to decide the type of training so that you can focus on the corresponding phases of the shot. The final score will be the sum of the scores on each of the different parts of the archer's body posture.

4 Experimental Setup

In this section, we describe the experimental details followed in the rest of the paper. The configuration of the system and shooting characteristics used in the experiments presented here are as follows:

- Target is 18 m away.
- Outdoor.
- Recurve bow left-handed, with a power of 36 lb and bow length of 66".
- Traditional instinctive shooting style.
- Camera 1m. away from the archer.

We locate the target 18 m away form the archer because, according to the World Archery[1], it is the official basic distance for shooting both outdoors and indoors. The recurve bow is usually the recommended one for beginners. The bow is left-handed since the archer is left-handed (the case for the right-handed would be symmetrical).

In this work, we use traditional instinctive style instead of Olympic shooting style because the Olympic bow is more complex. The Olympic bow has more gadgets than the instinctive bow such as stabilizers, sight, and clicker. Besides, the instinctive style allows us a better image treatment and gives us greater freedom in body posture.

Figure 2 presents a brief outline of the positions of the archer and the target on the archery field. The camera was placed 1 m from the archer, this position allows the correct detection of the most relevant joints for the system.

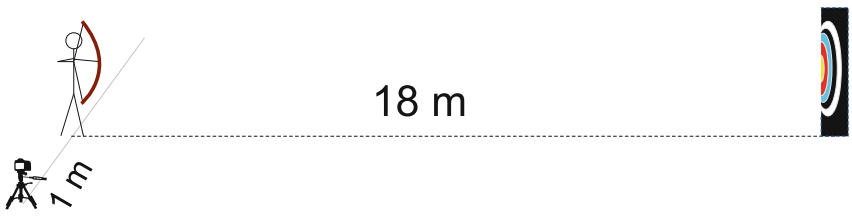
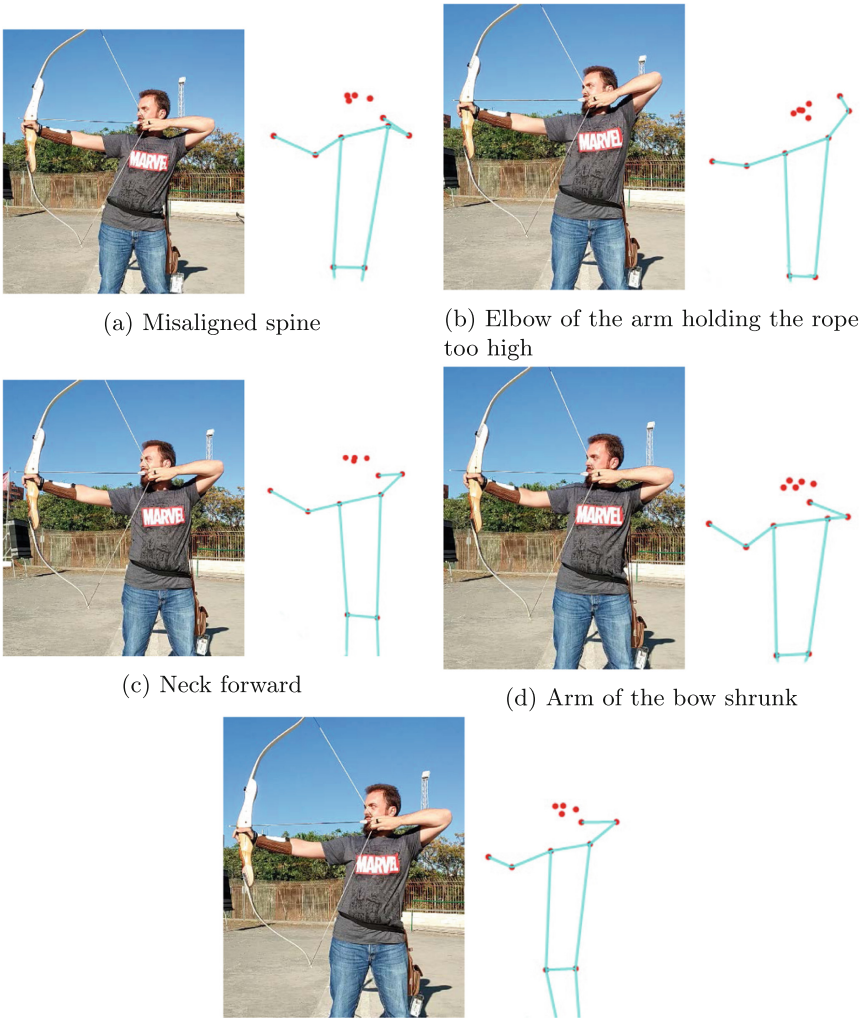


Fig. 2. Scheme of the elements in the archery field.

In this experiment, we focus on the main shooting phase: aiming. Commonly, beginner archers perform several wrong body postures. Our system can detect these postures and report them to the user. We can see in Fig. 3 the pictures of the most common wrong body postures during the aiming phase which we take into account in this experiment. It is noteworthy that these wrong body postures do not necessarily imply a low performance in terms of shooting precision. However, as the training progresses, they can lead to various injuries or health problems that make it impossible for them to practice any sport. For this reason, it is important to learn correct body posture from the very moment you start the archery practise.

[1] World Archery website: https://worldarchery.org/.



(a) Misaligned spine

(b) Elbow of the arm holding the rope too high

(c) Neck forward

(d) Arm of the bow shrunk

(e) Misalignment of the arms

Fig. 3. Examples of pictures and body diagrams of anomalous postures detected by ATILA.

5 Preliminary Results

To show the viability and use of our system, we present here some preliminary results. A beginner archer made a total of nine shots with the characteristics described in the previous section. Intending to show how the system detects incorrect positions, we consider two types of incorrect postures in this experiment: misaligned spine and raised elbow. For each of them we have calculated

two indicators δ_1 and δ_2 as follows:

$$\begin{aligned} \boldsymbol{c_1} &= [hip_{right}, shoulder_{left}] \\ \boldsymbol{c_2} &= [hip_{left}, shoulder_{right}] \\ |\boldsymbol{c_1}| - |\boldsymbol{c_2}| &= \delta_1 \end{aligned} \tag{1}$$

in the case of a misaligned spine, and

$$\begin{aligned} \boldsymbol{e_1} &= [wrist_{right}, wrist_{left}] \\ \boldsymbol{e_2} &= [wrist_{left}, elbow_{left}] \\ \boldsymbol{e_3} &= [wrist_{right}, elbow_{left}] \\ |\boldsymbol{e_1} + \boldsymbol{e_2}| - |\boldsymbol{e_3}| &= \delta_2 \end{aligned} \tag{2}$$

for the rised elbow.

The system assigns a score, that represents the quality of that body posture, to each type of irregularity in the shot to calculate the final score ($score_{Final}$). Each partial score is in the range 0–4 being 0 the worst score and 4 the best score. Table 2 presents the conditions for each δ_n and the score attached to the body posture. In this way, we calculate the quality of the shot by adding the scores of both incorrect postures $score_{Final} = score_{\delta_1} + score_{\delta_2}$. This formula allows us to easily evaluate ATILA in this proof of concept.

Table 2. Scores for the wrong postures misaligned spine and rised elbow.

Score	Misaligned spine	Rised elbow
0	$20 \leq \delta_1$	$100 \leq \delta_2$
1	$15 \leq \delta_1 < 20$	$75 \leq \delta_2 < 100$
2	$10 \leq \delta_1 < 15$	$50 \leq \delta_2 < 75$
3	$5 \leq \delta_1 < 10$	$25 \leq \delta_2 < 50$
4	$\delta_1 < 5$	$\delta_2 < 25$

Table 3 summarizes the indicators and score of each shot returned by our system. Overall, the shots obtained quite high scores. In particular, the first shot was virtually free of the injuries analysed. It means that the archer made a correct body posture. However, the shots 3,7 and 4,6 are of special interest for the archer since, although the archer did not get a low overall score, they can be dangerous and produce an injury (partial low scores). The archer did not achieve perfect punctuation in any shot mainly because of the misalignment between shoulders and hips. The analyzed data are very interesting because both wrong postures seem to be related. When the archer correctly aligns the spine, the elbow will be in an incorrect place, and vice versa. The last two shots (8 and 9) got a final score of 0. This is because the archer performs a wrong posture intentionally to test the correct operation of ATILA.

We believe that these results are a good starting point to work on since ATILA has detected 4 possible injuries of both types in 9 shots. Also, the usefulness of ATILA is confirmed considering the identification of these guidelines in shots makes that the archer accelerates her/his learning.

Table 3. Coordinates of each articulation, indicators and final score. We marked the lowest scores, 0 and 1, (incorrect body postures).

Shoot	δ_1	δ_2	Misaligned spine score	Rised elbow score	Final Score
1	5.35	13.28	3	4	7
2	11.76	31.41	2	3	5
3	24.38	24.22	0	4	4
4	8.14	85.05	3	1	4
5	14.16	6.82	2	4	6
6	1.73	75.72	4	1	5
7	15.25	0.12	1	4	5
8	26.07	182.41	0	0	0
9	35.34	243.86	0	0	0

6 Conclusions

In this article, we have presented ATILA, a system for monitoring and reducing injuries in archers, mainly beginners. Advances in machine learning and image processing are the basis of this system. Our proposal can analyze the body posture and discover positions harmful to the athlete using images obtained by a camera or smartphone. Results show that in 9 shots, ATILA detects 4 misaligned spines and 4 raised elbows, postures that should be corrected to avoid injuries related to these body parts. It is noteworthy that the system shows overwhelming advantages in terms of injuries detection, which justify the effort devoted to its research and development. Moreover, as far as we know, there is no similar system.

In the next stages of the work, we will develop in greater depth the system creating a more intuitive and useful interface for the final user, with the aim of testing the system daily in a real-world archery academy in Malaga (Spain). Also, to improve the accuracy in the detection of injuries, we will use a greater number of cameras, as well as video sequences to analyze other phases of the shot. All of this will allow us to train the neural network with a high amount of domain-specific data. In the meantime, body postures will be analyzed, not only to reduce injuries but also to improve the quality of the shots and thus actively assist in the training of the archers.

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