Integrated multi sensors and camera video sequence application for performance monitoring in archery

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Abstract. This paper explains the development of a comprehensive archery performance monitoring software which consisted of three camera views and five body sensors. The five body sensors evaluate biomechanical related variables of flexor and extensor muscle activity, heart rate, postural sway and bow movement during archery performance. The three camera views with the five body sensors are integrated into a single computer application which enables the user to view all the data in a single user interface. The five body sensors’ data are displayed in a numerical and graphical form in real-time. The information transmitted by the body sensors are computed with an embedded algorithm that automatically transforms the summary of the athlete’s biomechanical performance and displays in the application interface. This performance will be later compared to the pre-computed psycho-fitness performance from the prefilled data into the application. All the data; camera views, body sensors; performance-computations; are recorded for further analysis by a sports scientist. Our developed application serves as a powerful tool for assisting the coach and athletes to observe and identify any wrong technique employ during training which gives room for correction and re-evaluation to improve overall performance in the sport of archery.

1. Introduction
Development of innovations in sports sciences and engineering has provided a solution that reinforces the utilisation of inertial measurement units (IMUs) and wearable sensors as a powerful device for the measurement and tracking of athletes in different sports as an alternative to the use of motion analysis laboratory [1]. The IMUs which consist of gyroscopes and accelerometers as well wearables sensors such as Electromyograph (EMG) and Electrocardiogram (ECG) can be used to monitor athletes’ performance with respect to speed, position and physiological responses during a sporting performance by integration of the sensor data [2]. The combinations of these sensors have shown to be cost effective and reliable in tracking and assessment of athletes’ performance in diverse sporting activities [3,4].
Archery is a static and non-contact sport that requires the archer to be acquainted with the synergies of certain performance variables viz. physiological, mechanical as well psycho-fitness variables which either directly or indirectly influence the outcome of performance in the sport. The previous researchers have described that the capability of the archer to control his or her postural sway, heart rate and activation, as well as relaxation of the relevant muscles, is resulted in shooting consistency and consequently contribute to higher archery scores[5,6]. Nevertheless, for an archer to be acquainted with all the information on the aforementioned performance variables during archery performance, there is a need for an interactive device that can deliver the information in a real time for analysis and evaluation. Moreover, to the best of the authors’ knowledge, the development of software and database system for monitoring archery performance proposed in the present investigation is still in infancy. Hence the purpose of the current work is to develop a comprehensive archery performance monitoring system which consisted of three camera views and five body sensors using a single user interface.

2. Materials and Method
The procedures for the development of the present system was undertaken under the following sequential order:

2.1. Sensors development
A total of 2 IMUs and two EMG wearable sensors are embedded into the system to determine the postural balance, movement of the arrow, muscular activations of the muscle flexor digitorum and extensor digitorum and the heart rate of the archer. For the assessment of postural sway, an accelerometer is tied to the pelvic region of the archers which is the centre of gravity that controls the static stability in human. To determine the movement of the bow, a gyro sensor is attached to the hand of the archer gripping the bow in a glove to hold the sensor tightly. Furthermore, bipolar electrodes are connected to the sensor by enabling the heart rate detector to detect the heartbeat of the archers from the wrist. Equally, two sensors are attached to the left muscle extensor digitorum and the right muscle flexor digitorum to obtain Electromyography signals during the performances of the archery related movements. All the data can be streamed in real time at the desired sampling rate and can be transmitted via Bluetooth for further analysis. The sections of all the sensors attachments in the body are shown in figure 1:

![Figure 1: IMUs sensors’ location attachments in the archer’s body.](image-url)
2.2. Camera integrations
Cameras have become ubiquitous in monitoring archery training performance. A camera system can help the archer together with their coaches to review their techniques during training. A more advanced camera system such as high speed camera system [7] allowed precise technique execution as well as injury prevention such as rotor cuff.

In this paper, a three way camera view is deployed simultaneously to record every archery action during training from three different viewing angle of the archer namely from the front, from the top, as well as from the side. When reviewing the action from this three camera angle, archer and coaches can easily recognize correct form and posture as opposed to the wrong during stance, drawing, aiming and release phase of the arrow. By reviewing the video footage, an improvement can be made for the archer’s technique.

The camera system described in this paper also has the capability to capture the archer action in “live” mode. One of the advantages provided by the “live” mode is the ability for the archer to receive feedback immediately from the coaches while standing, drawing, aiming and releasing arrows. This will help the archer to develop muscle memory of proper technique rather than waiting for a special review session after training [8].

2.3. Psycho-fitness assessment
The Athletic Coping Skills Inventory (ACSI), an instrument for assessing athlete’s psychological skills, developed by previous researchers was selected [9]. This instrument is considered apt for evaluating the psychological skills of the archers in this study because of its connection to the nature of archery game as an individual sport rather than a team sport. The instrument measured seven basic psychological constructs namely; Coping with Adversity, Coachability, Concentration, Confidence and Achievement Motivation, Goal Setting and Mental Preparation, Peaking Under Pressure, Freedom from Worry.

On the other hand, standard physical fitness evaluation which consists of vertical jump, standing broad jump, stork balance, hand grip, core muscle strength test were implemented. These psycho-fitness assessments are integrated into the system and key in offline before the online measurement of the biomechanical variables.

3. Results and Discussion
The output of this paper is the software development to integrate all the necessary sensors and the camera view into one single performance monitoring interface. The software is developed using Microsoft Visual Studio Community 2017 Version 15.1 in a Windows Forms Apps. The entire programmed is coded using C# language. The software is divided into two main component namely the data entry for psycho-fitness analysis and the camera view with biomechanical analysis.

From the instrument described in 2.3, an interface for storing the psycho-fitness analysis for each archer is shown in figure 2. The psycho-fitness variables are assessed offline and key into the system which could predict the level of the psycho-fitness ability of the archer through an integrated equation. The psycho-fitness data give the indication of the performance of the archers given that the psychoanalysis data is gathered consistently once in three months or a week before a tournament. Similarly, the interface is working together with an embedded database features in Microsoft Visual Studio. The manipulation of the data such as insert, update, select, or delete is programmed through SQL Client query inside the database. All the data inserted into the database can be exported into comma-separated values (.csv) form. This .csv form allowed for data sharing between archer and coaches as well as coaches and coaches to track individual archer progress in term of psychological readiness and fitness performance. As reported by Suppiah P K et al. [6], psychological readiness and fitness performance are key components for the archer to prepare for a competition such that in highly rated psychological readiness and highly rated fitness, the archer is expected to perform well in the competition.
Figure 2: Interface for Psycho-Fitness Analysis Data Entry.

The other main part of the software development is the display of live camera and all measurements from the sensors simultaneously. The live camera displayed is programmed using Emgu.CV library while the sensors are read from Bluetooth. Thus, the software needs a Bluetooth enabled computer to run. The data streaming from three cameras and five sensors through Bluetooth can put a significant burden on the computer processor to compute in real time. Therefore, the five sensors are programmed in a multithread environment embedded in Microsoft Visual Studio. The term “Threading” in C# programming language refers to a coding section which enables concurrent processing of operation at one time. The data stream from the Bluetooth also being displayed in “live” line chart form in the interface. The interface for the camera view and the chart form is shown in figure 3.

Figure 3: Interface for Camera Live View and Sensors.
The importance of the present developed system is the capability to capture the archer action in real time. This enables the archer to obtain feedback immediately from the coaches during stages of archery performance such as standing, drawing, aiming and releasing arrows. The opportunity for the archers to obtain real time feedback on their performance has been reported by the previous researchers to offer a substantiate benefit in developing muscle memory [8]. It could also serve as an avenue for immediate correction of any detected wrong technique rather than waiting for special review session after training.

4. Conclusion
The comprehensive archery monitoring system developed in this paper has shown ability in assessing postural sway, hand movement, muscular activation, heart rate as well as psycho-fitness variables different connected to the sport of archery as well as archers’ technique from three different viewing angle in one user interface. The developed system has shown that a comprehensive sensors integration from physical sensors attached to the archer to three different camera angles able to provide necessary information on every action executed by the archer which can go a long way in facilitating the archers to be conscious of his/her actions and any improper techniques to enhance their own performance. The next part of the system development which is still ongoing is the development of a deployable portable tower in which the cameras can be mounted for recording the archer’s performance in real time during training at the archery range.

5. References

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