A Mobile Application for Assessing the Strength Exercises on Sports Training Equipment

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***Abstract*—The progress in mobile technologies of Internet of Things (IoT) effectively supports the digitalization of sports training equipment. In this demo, we show an assistant mobile application (digital arbiter) to track the quality of exercise performance by the user. We experiment with sports training equipment produced by the MB Barbell company. The exercise is bench press from the chest or similar. The equipment has a mechanism to attach user's smartphone. The problem is to estimate the lower and upper bounds for each round of execution. The measurement is based on data coming in real-time from the smartphone accelerometer. First, the mobile application can check the correctness as reaching the bounds. Second, the distance and time are estimated that the user has overcome during the exercise rounds. Since each user has own characteristics (e.g., arm length, grip method), individual calibration of the sensor system is needed before exercise performance on a given sports training equipment. Our experiments show that the mobile application has good accuracy and real-time performance, so the digital arbiter can be used as in individual daily physical activity or in mass sports events.**

I. Introduction

In the sport events, there is often a need for a correct assessment of the performance of the exercise, which will help in controversial situations, and also make the approach to refereeing automated. Such judging can be implemented with the help of electronic computing equipment, called a digital arbiter, which makes it possible to exclude the human factor when assessing the correctness of the exercise [1]. To solve the problems listed above, we have created a digital referee system that is responsible for checking the quality of the performed repetitions, and also provides you with all the statistics of the completed exercise. A feature of the developed system is the use of a standard set of equipment for data acquisition. An accelerometer sensor installed in mass-produced smartphones was chosen as such equipment. The report organised as follows. In the first part we set the problem of the exercise tracking. After that we propose a solution to evaluate correctness of repetitions on the training machine. Finally, we conduct an experiment to evaluate the ability of the developed solution to recognise correctness of repetitions.

II. Tracking the Exercise Performance on Sports Training Equipment

The prototype consists of an Android OS mobile application designed for a smartphone with the corresponding OS, and capable of receiving data from the sensor for further processing, to perform the following functions:

1) Calibration functions
2) Functions for counting the correct number of repetitions.
3) Functions for determining the time of passage of a given distance by the hands of an athlete.
4) Functions for determining the distance traveled by the hands of an athlete for a given amount of time.
5) Functions for displaying statistics on the results of a working approach for each repetition
6) Functions for displaying statistics on the results of all approaches, functions.

These functions, and the application structure are presented in architecture model, shown on Fig. 2.

The developed mobile application allows you to control the performance of exercises on the machines necessary for the athlete. If the athlete performs a repetition with sufficient amplitude (corresponding to the calibration), the application notifies him of the correctness of the repetition. If an athlete performs an exercise with insufficient amplitude, the repetition will not be counted. The exercise can be performed in the classical mode - fixing approaches at a pace convenient for the

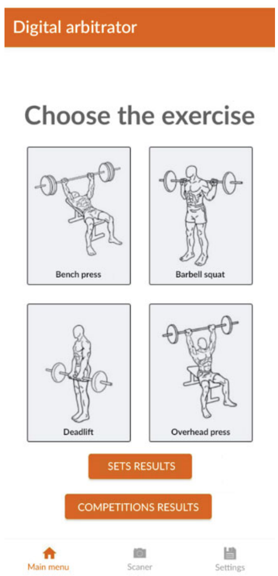

Fig. 1. Main menu of the application

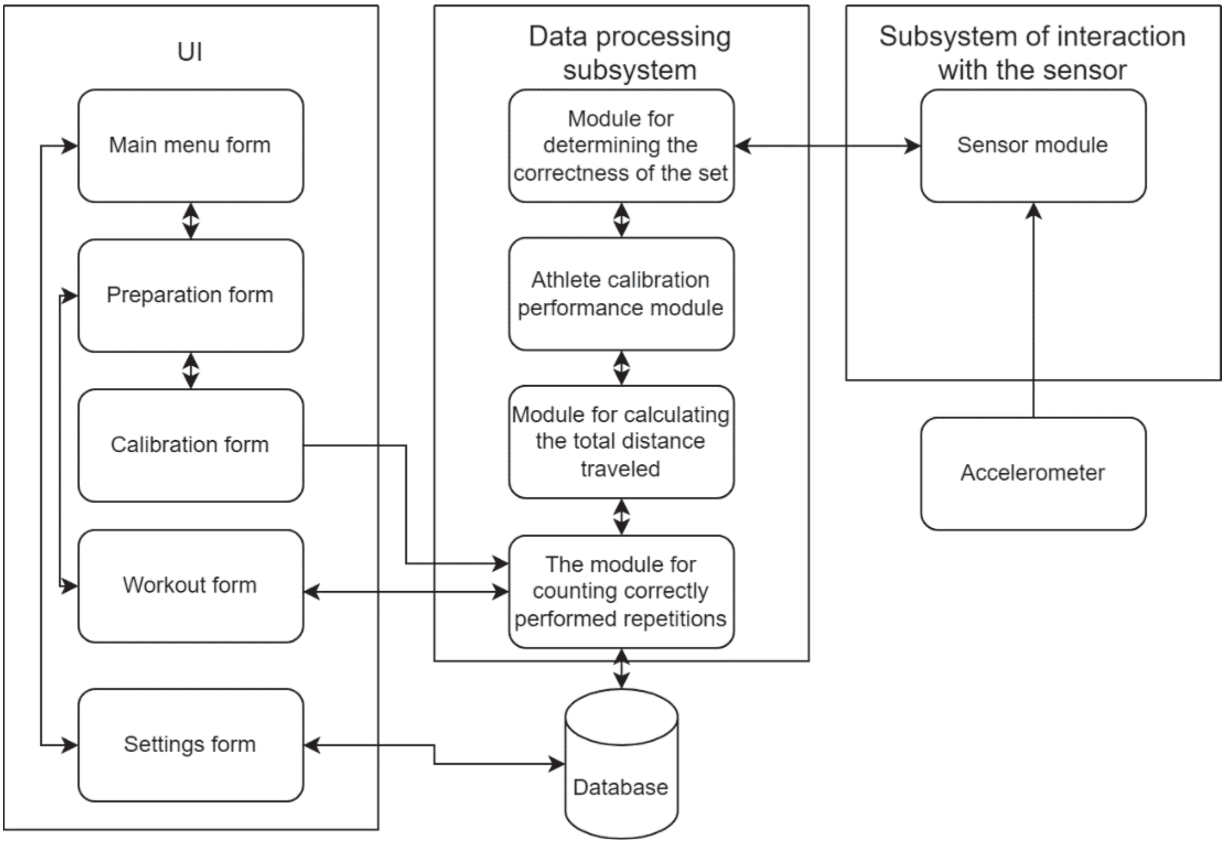

Fig. 2. System architecture

athlete. Additionally, there are two competitive modes in which the athlete: needs to perform the largest number of correct repetitions to achieve the specified total distance traveled in the shortest time; it is necessary to perform the greatest number of correct repetitions in the allotted time, by which the total distance traveled is determined. After the completion of the set, the athlete can view the statistics of this set for the classic mode [2]. The main menu (UI) of the application showed on fig. 1.

III. Algorithms

We decided to use accelerometer as a main computing compound. It is used to get the angles between the vertical and the lever of the machine used. As accelerometer used in mobile phones provides you with the data, including the acceleration of gravity, we can calculate the current angle of rotation around Y-axis of the smartphone using the following formula:

$$p_i = arctan(-1 * \frac{X_i}{\sqrt{Y_i^2 + Z_i^2}}) * \frac{180}{\pi}, \quad (1)$$

where X_i, Y_i and Z_i stands for axis accelerations of X, Y and Z. Thus, the structure of the architecture of the system is depicted on 1.

The developed application consists of the following modules:

Athlete calibration performance module [3]. This module computes calibration angles of lower and upper position to evaluate correction of repetitions.

- After converting the data received from the accelerometer, the input of the calibration function continuously receives the values of the angle pi, where i corresponds to each subsequent time interval.
- If n values of p_i obtained in a row differ from each other by no more than a constant ϵ, then it is considered that the user has fixed the simulator in the upper or lower position.
- When the user reaches the specified number of calibration repetitions, the calibration values are calculated by averaging the obtained angles for the lower and upper positions.
- The obtained angles for the lower and upper positions are entered into the database. The Obtained angles are shown in calibration screen (UI) on fig. 4

Module for determining the correctness of the set [4]. This module validates correction for each repetition form accelerometer on-line.

- The calibration values of the upper and lower angles are retrieved from the database.
- After converting the values obtained from the accelerometer, the values of the angle p_i are contin-

uously fed to the input of the working approach function. If k sequential p_i values obtained in a row reach the calibration values by 95%, then the repetition is considered valid.

The module for counting correctly performed repetitions [5].

- Each correctly performed repetitions are summed up, and the execution time is fixed for them, as well as the distance covered by the athlete's hands.

Module for calculating the total distance traveled [6].

- To calculate the distance traveled by the hands of the athlete, it is necessary to measure the length of the lever from the location of the sensor (smartphone) to the axis of rotation of the simulator frame. Based on the angles α_1 (at the highest point) and α_2 (at the lowest point) obtained for each repetition and the length of the lever L, the path S is calculated:

$$S = \frac{\pi * \beta}{180 * L}, \tag{2}$$

where $\beta = |\alpha_1 - \alpha_2|$, α_1 and α_2 are calculated as the average of all angles reaching 95% of the calibration value for each repetition.

Database module.

- A local database with a SQL-like syntax is used to store the arm lengths, as well as the calibration value of each type of simulator.

IV. Experiment

Fig. 3. Used simulator for experiments. The smartphone holder is installed on the right side on the movable frame.

For experimental research and approbation of the developed algorithms, an exercise machine of the company "MB Barbell" of the "Bench press" type with adjustable weight was used. The experimental setup is shown on fig. 3. Additionally, for the demonstration, MB Barbell lever-type exercise machines were used to perform exercises: "bench press", "squat", "deadlift" and "overhead press", installed on the embankment

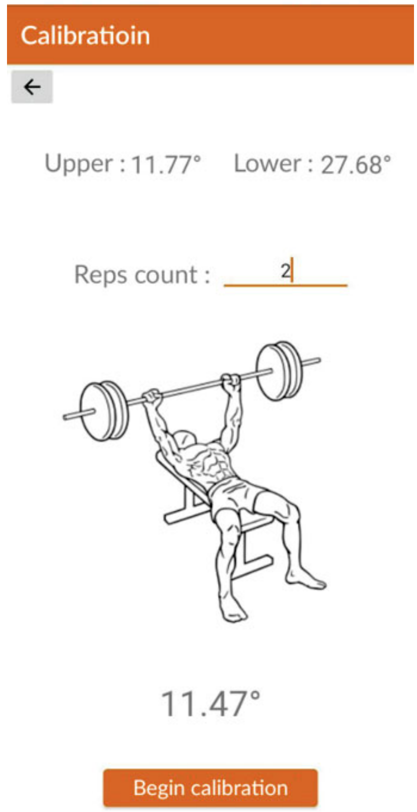

Fig. 4. Main menu of the application

of Lake Onega. A smartphone with pre-installed smartphone software is fixed on them with a latch in a certain position. The attachment point of the latch is located at a pre-measured distance from the axis of rotation of the frame of the simulator.

The purpose of the experiment: to evaluate the performance of the prototype based on two calibration repetitions and five subsequent working (load) sets with a weight of 40 kg.

Testable properties of the prototype: general operability - the ability to catch the angle of the simulator position with this type of sensor. Ensuring the declared accuracy of 90%.

Expected result: the deviation of the readings of the working approach from the calibration one for the movement of the athlete's hands should not exceed 10%.

V. Conclusion

According to the results of the experiments, shown on fig. 5, the digital referee system shows a good accuracy of fixing the performed repetitions - up to 95%. The error used for evaluation when performing the exercise is 5% of the value of the calibration amplitude. The overall accuracy of the developed algorithm is about 90% - such a part of correctly performed exercises will be correctly recorded. The application was tested by athletes with different physical data (arm length), when performing repetitions with different intensities, as well

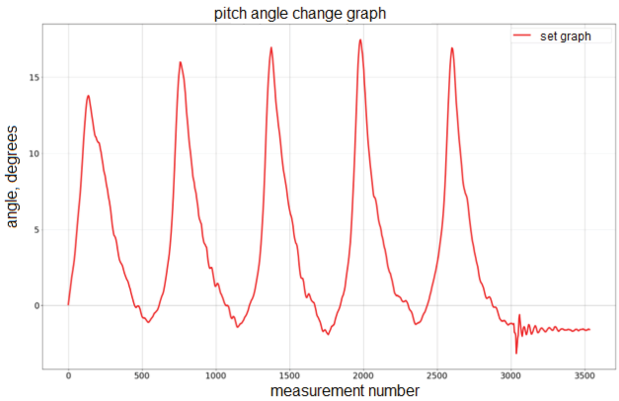

Fig. 5. Graph of pitch angle p_i change of the movable frame of the chest press machine when doing exercise

as with different set weights. Further research is aimed at improving the algorithm of the system, adapting it to work with different intensity of performance, as well as adding a function for determining the error from the weight set by the athlete to perform the exercise.

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