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Race-walking Detection through Piezoelectric Sensors and Graphical Programming

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Abstract
Fault detection in race-walking has been a topic of discussion each and every time a major sport event like Olympics is on display. Hence many attempts have been made accurately detect the bent knee and loss of contact during the event. Here we discuss a cost-effective method using graphical programming to accurately detect the loss of contact during the training sessions in university athletes. A piezo-electric sensor system in implemented together with NI-myRIO. We differentiated walking, running and race-walking patterns with the help of histograms of peak time differences between main peaks and sub-peaks.

Keywords: race-walking, graphical programming, labview, loss of contact.

1. Introduction

Race walking stands apart from other sports that need big energy bursts because it is a disciplined and precise activity. It is thought that the race walking originated when nobility in the Victorian era wagered on their footmen as they walked next to horse-drawn carriages. In England, this pastime eventually became formally recognised as a professional sport, and a set of regulations were formed. The regulations are straightforward; the athlete must always have one foot on the ground. The same infraction is known as loss of contact (LC). When the supporting leg, the one in touch with the ground, is not kept straight throughout the foot contact time, the knee-bent (KB) is the second probable infraction. Varying on the competition judges from five to nine observe races for violations. They contain paddles marked “loss of touch" (~) and “bent knee" (<) symbols. A candidate is disqualified if they are shown three paddles from separate judges, including the chief judge. However, since high-tech cameras are focused on athletes at significant events like the Olympics, there has been controversy over pictures suggesting that competitors’ both feet are elevated above the ground. The International Association of Athletics Federation (IAAF) regulation for race walking in the country explicitly states that judgement is only dependent on the range of human eye detection. However, the technological advancements have enabled the detection of these faults at early stages of a career and addressing the issues. This is beneficial for athletes succeed. Many research groups have used various detection methods to detect the anomalies.

2. Literature Review

Taborri and his team detected illegal steps in race-walking using initial sensors which are placed on the lower limb segment. Their detection is done automatically with gathered data from those sensors using machine-learning algorithms. ML algorithms have performed well in identifying both the losing contact fault and the Knee bending fault. Further, their study mentions the importance of wearable components in detecting faults during practice and competitions [1]. J.B. Lee and his team used a single inertial sensor which is placed on the vertebra, and a high-speed camera simultaneously to detect the loss of ground contact during race walking and compare the results. It presents that the sensor results are more accurate than the results provided by a high-speed camera. The paper addresses the importance of wearable sensor devices to increase the performance of detecting faults in race walking [2].

T. Caporaso and S. Graizioso observed illegal steps by a single sensor, which is placed at the bottom of the spine, working along with IART (Initial Assistant and Trainer) algorithms. With this system, the infringements are also identified along with the evaluation of the performance of the sportsman. The analysis is done using five bio-mechanical indicators and presented with radar charts. The distortions of the charts highlight the infringements and the loose performances [3]. T. Caporaso with his team has done furthermore studies on measuring athletes' performances and detecting faults with the wearable inertial system that they have designed. They consider five parameters (Loss of ground contact time, loss of ground contact step classification, step length ratio, step cadence, and smoothness) for the evaluation. Here they validate those parameters using radar charts and show the importance of a wearable device in judging the race walking [4].

T. Caporaso is done a preliminary study on taking measurements and managing race walking to identify infringements and evaluate and discuss the importance of a wearable device. Here the results show the value of having individual profiles of athletes with the data obtained by an electronic system [5]. C. Little and his team used a wearable sensor on the sacrum of the athlete and detect the differences between normal walking, fast walking, and running. As well as they have confirmed that there is no significant difference between the movement of a sportsman on a treadmill machine and on the ground. Here they address the importance of using initial sensors in taking measurements in the health and sports industry [6]. G. Di Gironimo and his team have conducted an experimental analysis on motions during race walking using an optical motion capture (MOCAP) system and a force platform. There they used ten infrared digital cameras for kinematic analysis and eight integrated force platforms for dynamic measures. Here the new motion analyzing protocol has given quite similar results compared to other conventional methods. But this developed method can be used to enhance the technical knowledge of race walkers and important method to increase performances [7].

In another study by G.D. Gironimo, the results obtained by the inertial system, which is worn at the vertebra, are validated in different speed ranges with an e-bike consisting of a high-speed camera. Results have proved the system can detect Lost of Ground Contact fault with higher accuracy, and it can give a significant assessment in detecting faults [8]. T. Suzuki and his team trained a machine-learning program to identify the contacting losses during race walking using the judgements of well-experienced and qualified referees. After the validation tests, the program was performed with over 90 percent accuracy. But the validation of this system is done with intentional faulty walking. Therefore, this system should be trained with natural faulty walking videos [9].

M. Skublewska-Paszkowska with his team used a Vicon motion capture system to analyze the workload on legs (especially in the knee joint) born during race walking along with MATLAB software. The knee deflecting angle and race walking speed are also parameters that they used in testing algorithms [10]. Triboelectric nanogenerators (TENGs) have made significant progress in energy harvesting and monitoring of human motion. The WS-TENG can generate electricity in a curved state, and this feature can be used to monitor whether athletes break the rules in the process of race walking. This design will promote the development of an athlete monitoring system [11].

Y. Shao and his team, in their study, the race walking is monitored using a triboelectric nanogenerator (FDA-TENG). Here they get an accurate electrical output from the system. By analyzing data, judges can find out the violation of rules [12]. Didik R. Santoso with his team has designed a real-time operating system to detect the differences between running and walking. There is an insole sensing unit (RTU) in the system designed with a piezoelectric stress sensor module and a signal processing unit (MTU). The wireless communication between these two units is done by a radio transceiver device. By the study, they highlighted the need of judging using modern instruments to avoid faulty decisions [13].

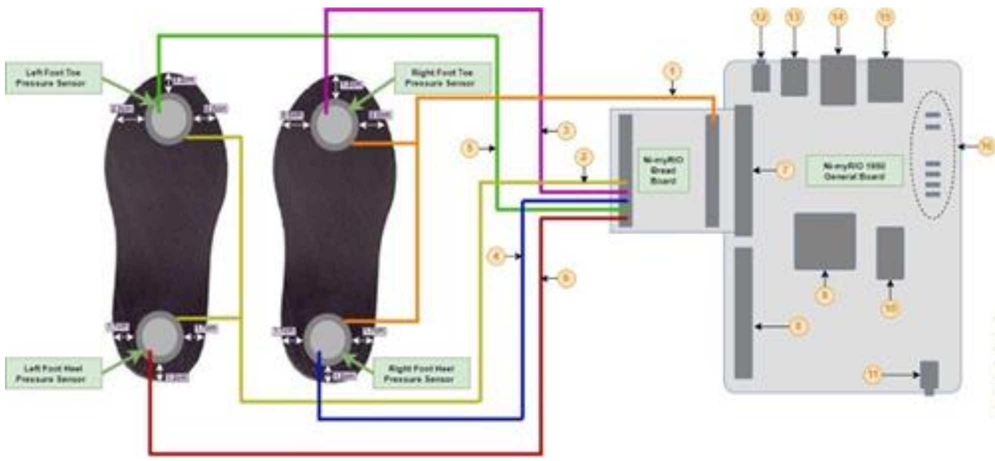

Fig. 1: Sensor's placement and myRIO connection diagram (1-6 are connection wires, 7 - MXP Connector A 8 - MXP Connector B, 9 - Processor/FPGA, 10 - DDR3 Memory, 11 - User Button, 12 Reset Button, 13 - Power Connector, 14 - Devise USB Connector, 15 - USB Connector, 16 - LEDs).

B. Hanley, along with his team, presented a study on the advancing of non-visible illegal steps in race walking. There they used a panning video camera (50 Hz), a high-speed camera (100 Hz), and three force plates (1,000 Hz) and analyzed the accuracy and measured the fight time ranges of illegal steps. Furthermore, they have divided race walking judges according to their detection rates, and as a result, they address the importance of electronic chip insole technology to detect the infringements [14]. Y. Wei and his team, in their study of the movements in race walking, are analyzed using MCODE (an unsupervised classification method). The data are collected by accelerometers embedded in smartphones, and it is more practicable and provides sufficient accuracy to identify the illegal steps on race walking. Further, they proved that the MCODE method is more efficient than the conventional K-MEANS methods [15].

G. Dona, along with the team, explored mainly the knee bending process during race walking and its effecting of it on performance. There they show the importance of functional principal component analysis. The study is done using an opto-electronic system and a force platform [16]. All these studies pointed towards illegal race-walking detection using optical method, mechanical or motion sensory methods. But we are interested in developing much simpler device that can be replicate results using piezo-electric sensors and simple data acquisition units using graphical programming power of LabVIEW.

3. Methodology

The initial set of trials were done using Arduino (ATmega2560-based microcontroller module) + LabVIEW. Piezoelectric sensors (an active sensor) are carefully placed on the inner shoe sole (replaceable) as in the figure and connected to analog inputs of the Arduino. Arduino microprocessesor can acquire data with 10-bit resolution. Later we implemented NI-myRIO 1950 (myRIO) + LabVIEW to data gathering, where myRIO board has 12-bit resolution with higher sampling rate from 4 analog inputs. The sample for data gathering consists of university level race-walking athletes. We took data from both men and women and analysed using Origin Pro (statistical software).

4. Results and Discussion

The Figure 2 shows a typical output of a controlled race-walking given from the developed system. Where LH -Left Heel, LT - Left Toe, RH - Right Heel and RT - Right Toe signals from the piezo-electric sensors. Arbitrary units were used everywhere because the maximum amplitude of all the signals were around 6 volts and need of normalising the signals were not arise. But it is very important to note that the signals can be drastically improve and fine tune by using more sensitive and accurate pressure sensors, and of course that will be expensive. Also these sensors are placed only at a specific region under the shoe sole is somewhat adverse as the toe/heel signals are delocalized. This is clearly visible from the uneven amplitudes of sub-peaks shown in the RT signal. But as we obtain uneven amplitude sub-peaks for LH signal pushed us to think the placement of heel sensor also affecting the signal. Once again, the other main consideration of this case is that the accuracy and the quality of the sensor.

Once the signal resolution is increased, a pattern for peaks in all three cases (race-walking, running and walking) is discernible and denoted as main peaks - with higher amplitude and sub peaks - with lower amplitude hereafter. The race-walking pattern is shown in the Figure 4. The main peak can be assigned with the main contact of heel/toe while the sub-peak of each sensor can be credited to the relaxation of the pressure sensor of subsequent contact release.

Direct observation redacted from comparing three cases of male player it was evident that race-walking can be distinguish from walking and running. As shown in the Figure 3 simultaneous and periodic peaks were recorded for the race-walking whereas almost impossible find a such case for both walking and running. Even though this is clear for the male player, signals taken from the female player is little irregular. This may be due to the fact that the shoe used to detect signals was not an ideal fit for her feet. Hence sensors placement might have been shifted from the optimum point. Thus, a development stage

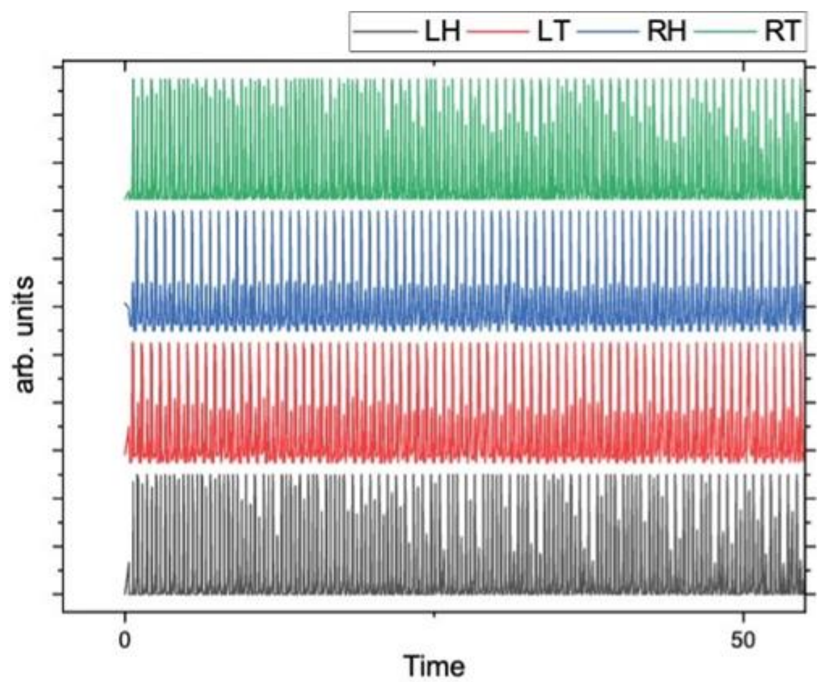

Fig. 2: Raw data with 10 millisecond acquisition intervals.

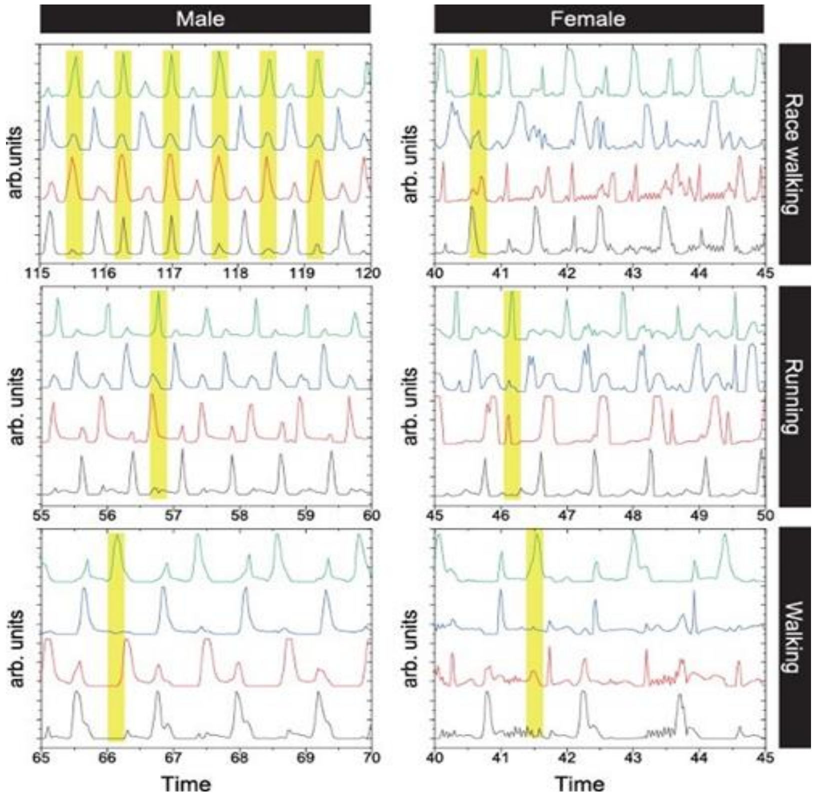

Fig. 3: Summary of data acquired from male and female player in three different cases walking, running and race walking.

Expected for design unisex, uni-size sensor kit for measurement. For the analysis aspects the study continued with male player data.

By analysing these distinct main peaks and sub-peaks, time differences between two consecutive peaks

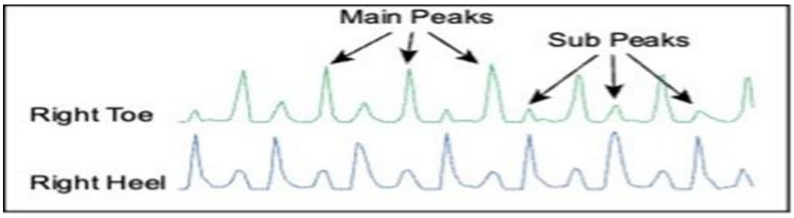

Fig. 4: Defining main peak and sub peak.

were calculated. Then the interval plots for each signal in three cases were derived. According to the results shown in the Figure 5 in each case race-walking had the lowest mean for each LH, LT, RH and RT signals as well as the lowest spread. A full comparison of male female and three cases are represented in Figure 5

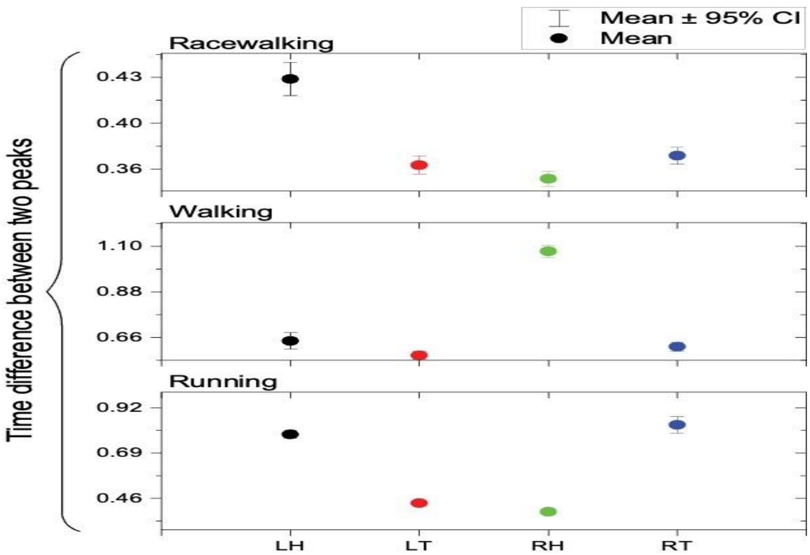

Fig. 5: Analysis of peak difference between two peaks.

This indicates the periodic nature and the symmetric nature of the race-walking signal and further proved by time difference histograms having similar timing values (Figure 6).

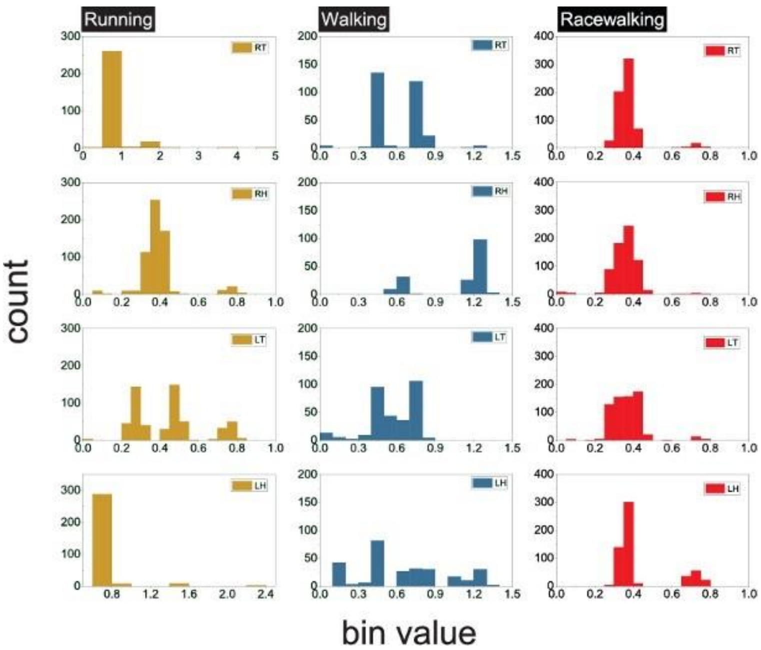

Fig. 6: Histograms of peak time differences in each case. Bin value represents the time different between two peaks.

In here a kind of second harmonic densities are visible in histograms, this can be attributes to missing peaks of signals causing two times the initial gap. According to current data pattern one can use two methods to accurately detect the race-walking. They are,

1. measuring accurate and finer signals to visually observe periodic simultaneous signals
2. use peak analysing methods to measure timings and observe histogram patterns

Even though the histogram data are quite inspiring it is difficult to implement such visualisation without lagging the output. In ideal scenario these experimental data should be replicated many times and analysed.

5. Conclusion and Recommendation

The current study is capable of elucidating race-walking from running and walking and thus the loss of contact. Also, this gives the coaching staff to work on fine tuning the techniques used by athletes. It is also recommended to increase the sample size to national and international level players to support the findings.

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