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Real-Time High Jump Wearable Device with ESP8266 for High-Performance and Low-Injury

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Abstract: In the world of sports, the injury is unavoidable, however, the performance is the first priority. The percentage of the athletes to get injured is very high due to the fallibility of athlete jumping themselves. Therefore, this study presents the design and implementation of high-performance and low-injury real-time high jump wearable device by using ESP8266 microcontroller. The proposed wearable device is built because of there is no device to monitor this sport during training. There are three (3) parts have been integrated to build this wearable device – input, process and output. The input consists of global positioning system (GPS) sensor that attached to the waist and force sensing resistor (FSR) sensor was placed at the bottom of the ankle as a wireless input for data captured. These data were then being processed by ESP8266 microcontroller hardware device with an embedded wireless fidelity (Wi-Fi) module on the same chip that has been programmed and results obtained were displayed via the mobile app. Graphical user interface (GUI) of the wearable device has been designed using C language code using OpenHAB software and data from the wearable device were also available in log formats. The outcomes obtained have shown encouraging results since all data can be visualised and monitored in real-time, history of the training can be retrieved and the benchmark data acts as a guide to the other athlete to improve the performance.

Keywords: ESP8266, Wearable device, Real-time, Monitoring, Injury, High Jump.

1. Introduction

High jump is classified as complex cyclic-acyclic movements where the aim is to bring the jumper’s centre of mass to a maximum height when crossing the bar [1]. To attain high-performance and low-injury, attention to the high jumpers’ technique toward take-off is significant importance.

In the context of sports for higher learning institutions in Malaysia, several sports have been identified as a focus sport, including high jump. Recently, one (1) of the high jumper (Norshafiee Mohd Shah) from Johor Institut Sukan Negara (ISN) has been listed in the rank of 4th for the 2nd Youth Olympic Games.

In the world of sports, injury is inevitable, hence prevention is better than cure. The similar risk magnitude exists in this sport of high jump where injuries tend to happen in each athlete while jumping. Percentage of the athletes to get injured is very high due to the fallibility of athlete jumping themselves [2]. Accidents, poor training practices, or improper gear can decrease the performance of the athletes. Some people get hurt because they are not in shape. Besides, not warming up or stretching enough can lead to injuries.

Due to these concerns, high-performance and low-injury are crucial not only for athletes but also coaches. The coach needs their athlete to improve their performance at maximum level to win the game but, to do that it can cause injury to the athlete if they exceed their limit. Currently, most of the study in [3]–[13] used a hardware implementation model to investigate various considerations that affect optimum peak height and torque in a high jump. High jump athlete run at moderate speeds and set down the foot, from which they take off, well in front of the body. These studies explain the improvement of the athlete that jump at maximum height with a strong torque by referring the approach speed of take-off. However, there is no explanation that implements high-performance and low-injury to monitor as well as assist both parties, athlete and coach.

Complexity in addressing and accessing various data of high jumpers’ locomotor system [3]–[13] has resulted in vast challenges from a hardware implementation perspective. With the availability of advances embedded resources on recent microcontroller ESP8266 devices such as wireless fidelity (Wi-Fi) integrated and sensor node. The ESP8266 are also being increasingly deployed in wireless intensive application areas [14]–[18].

To overcome all these issues, this study proposed the design and implementation of high-performance and low-injury real-time high jump wearable device by using ESP8266 microcontroller. It is targeted that the proposed wearable device will be deployed for real-time monitoring

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systems that not only possible to retrospectively examine load-performance relationship [19], but importantly to try to reduce the risk of injury, illness, and non-functional overreaching. It is our aim that this system can provide a scientific explanation for changes in performance as well as to enhance the quality of the training programme.

Therefore, this study proposed real-time wearable device targeted for high-performance and low-injury. In general, the following specifications have been outlined to address the current indoor training platform. The proposed system must be able to:

i. visualise the data of training;
ii. store and retrieve the data and its history;
iii. connect the sensor wirelessly; and
iv. monitor performance and risk of injury based on any reference data.

The organisations of this paper are as follows. An overview of the related work is summarised in Section 2. Section 3 presents the design and implementation, while results and analysis are presented in Section 4. Finally concluding as well as future work remarks are given in Section 5.

2. Related Work

To reveal the importance of this study, a summary of contributions and implementations by the previous researchers are tabulated in Table 1. In brief, it can be concluded that this topic is still immature and further research needs to be carried out, especially concerning with the hardware implementation, concerning the elements of embedded electronics and bioelectronics instrumentation for sports engineering:

Table 1 Summary of the related work.

Refs.	Contribution				Implementation	
	1	2	3	4	5	6
[3]		✓			✓	
[4]		✓		✓	✓	
[5]		✓		✓	✓	
[6]		✓			✓	✓
[7]		✓	✓		✓	✓
[8]		✓	✓		✓	
[9]		✓			✓	✓
[10]		✓			✓	✓
[11]		✓		✓	✓	
[12]		✓			✓	
[13]		✓		✓	✓	✓
[20]	✓			✓		
[21]				✓		

Note:
1: Physiology, 2: Biomechanics, 3: Technology, 4: Technique,
5: Hardware, 6: Software

A close examination of the related works concerning with high jump [3]–[13], [20], [21] reveals about the complexity of this sport. It can be classified into several domains of study, including physiology [20], biomechanics [3]–[13], technology [7], [8] and technique [4], [5], [11], [13], [20], [21]. In a nutshell, hardware-based implementation [3]–[13] targeted for high-performance and low-injury appear as an encouraging research area, not only for the physiology and biomechanics itself, more importantly to enhance the area of bioelectronics and embedded hardware for sports engineering area.

To achieve high-performance, ability to resist a high level of physical strain, heavy demands on the condition and function of the athlete's locomotor system are promising. Langer and Langerova [1], conclude that injuries on the high jumpers' locomotor system were divided into the seven parts of the body and it includes foot, shank, knee, femur, pelvic girdle, spine and others [1]. It is worth mentioning that the injury issues were found to be located mostly:

i. on the take-off leg;
ii. in the lumbar and thoracic parts of the spine, in the knee joint of the take-off leg; and
iii. in the area of the achilles tendon.

To monitor the occurrence and pain in some parts of the locomotor system, an in-depth interview and focus group discussion have been conducted and reported [1]. A brief note by [1] and results as depicted in Fig. 1 reveals that most injuries of the locomotor system are caused by one or a combination of two (2) or more of the following factors:

i. high values of reaction process at the take-off;
ii. inadequate training load;
iii. unbalanced fitness training;
iv. imperfect technique of the take-off; and
v. anatomical disposition to injuries.

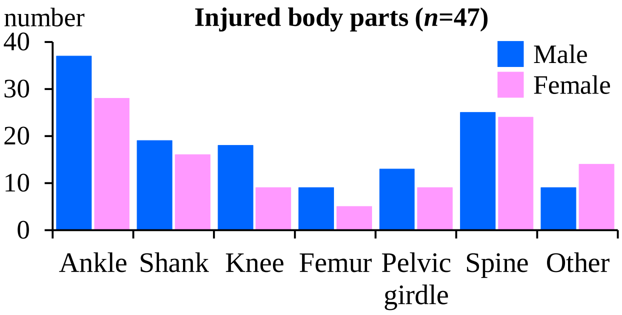

Fig. 1 The most frequently injured parts of the body with the top male and female high jumpers in the motivated sets from 1983 to 2005 [1].

As can be seen from the preceding notes, there still remains a huge gap for further research in bioelectronics area for high jumpers' locomotor system. A close examination of the existing monitoring practices in high jump reveals a huge gap, particularly for the hardware implementation, since most of the existing works contribute to theoretical [20], [21] and experimental [3]–[13] studies. Based on the comprehensive survey that has been carried out in high jump trend, the following key conclusions can be made:

i. the average approach speed at range $5.73 ms^{-1}$ to $8.40 ms^{-1}$ [3], [5], [6], [8]–[13], [20], [22] is the main parameter that can reduce the injury during take-off and increase the height of jump;

ii. there is no study on the hardware development, to be specific in the area of bioelectronics targeted for high jumpers' locomotor system;

iii. as diverse as the important contribution in processing, analyse and interpret data, an efficient real-time monitoring system will be able to reduce the gap between sport scientist, teams of athletes, coaches and the area of embedded bioelectronics instrumentation; and

iv. the advancement for both device development and monitoring application must be in line with their hardware implementation with various performance measures, such as area, power consumption and wireless transmission.

Finally, it is our ultimate aim to develop an effective and sustainable monitoring system that will lead to accurate and easy-to-interpret feedback for athlete and coach as well as the results can improve their training programme and finally provide a further avenue for all parties (athletes and coaches) and finally enhance high jumpers' performance.

3. DESIGN & IMPLEMENTATION

An overview of the proposed system of high jump wearable device is illustrated in Fig. 2 and ESP8266 microcontroller is selected for several reasons. The implementation of ESP8266 in real-time monitoring system is specifically to do tasks any others microcontroller cannot do efficiently, such as low-power consumption, small area and Wi-Fi integrated. The low-power consumption can reduce the capacity of supply current and voltage. Hence, it reduced the area take to build these wearable devices by using smaller battery size. Other than that, ESP8266 have been designed for transmit wirelessly, thus it can be a wireless sensor node. The use of ESP8266 in this project is to process all the inputs and display the output to mobile application (app). An overview of the method is discussed in the following subsection.

3.1 Input

Two (2) sensors, comprising force sensing resistor (FSR) and global positioning system (GPS) sensors act as an input to the device and all two (2) sensors were attached to the body. The GPS sensor is attached to the front waist to produce stable speed, while the FSR sensor is placed at the left and right ankles to gain the force at the ankle during the jump.

3.2 Process

In this research, two (2) ESP8266 microcontroller were used to processed GPS and FSR sensor inputs that produce speed and force of the athlete that was programme by Arduino IDE software. The data from the sensors will be sent wirelessly to the Internet router using built-in Wi-Fi in ESP8266 board. The used of two (2) ESP8266 acts as sensor node that send parallel data to the router.

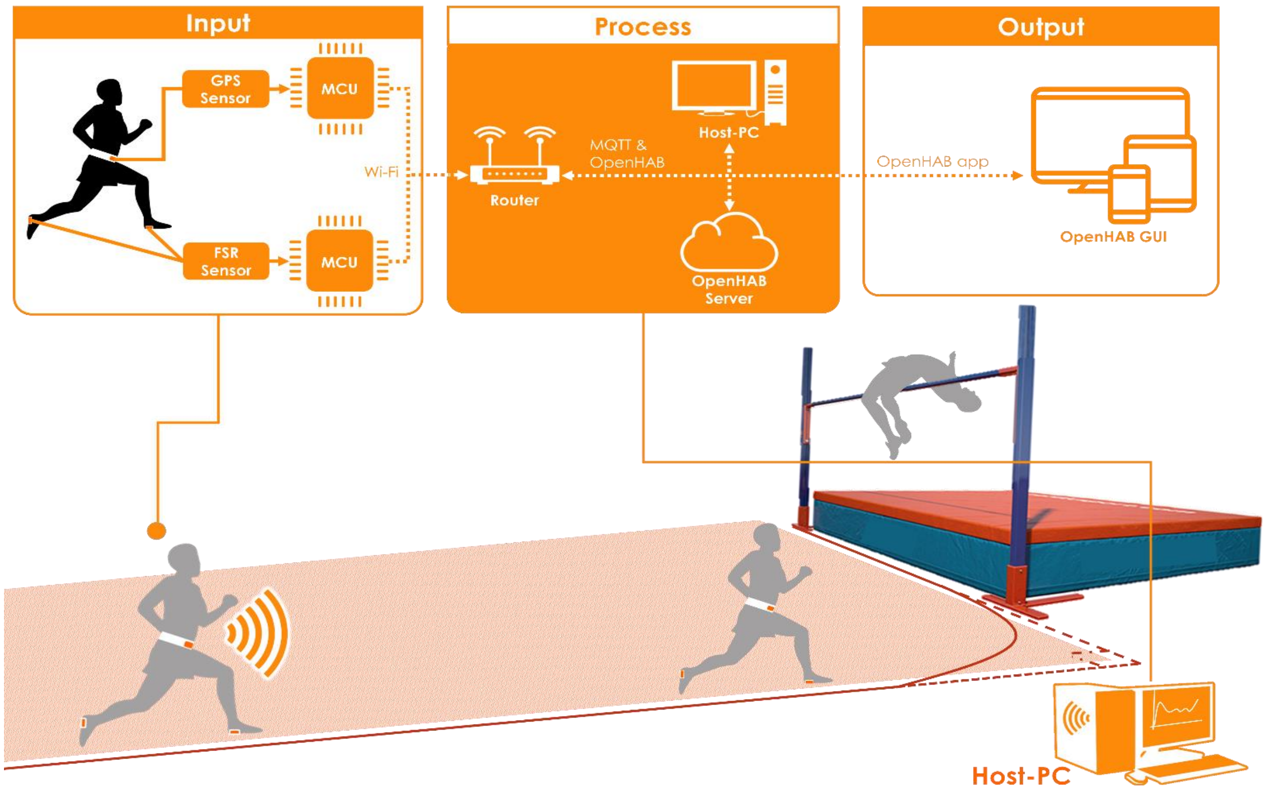

Fig. 2 An overview of the proposed system of high jump wearable device.

The main server (Host-PC) will find the sensors data based on Internet protocol (IP) address using message queuing telemetry transport (MQTT) software. The MQTT was designed as an extremely lightweight publish/subscribe messaging transport that functions to subscribe/receive input data from the ESP8266 to Internet via an IP address and publish/send the data to the OpenHAB software

OpenHAB is an Internet of things (IoTs) automation software that connect machine to machine (M2M) via IP address. The purpose of OpenHAB is to simplify the java language into C language levels and libraries segment that reduces the synthesising time taken to produce OpenHAB mobile apps. OpenHAB has a simple configurable graphical user interface (GUI), that named sitemap. The sitemap is a tree structure of widgets that define the different pages and content of the GUI. Widgets can be items that represent the current state of the athlete body speed and force data.

3.3 Output

The IoT take places in between microcontroller and the mobile apps. Where the microcontroller subscribe/publish the data to the mobile apps and the users subscribe/publish to the microcontroller to gain two (2) ways connection. The users that are athletes and coaches will analyse and improve the performance by looking at the data through any devices like smartphone, tablet and computer that have an Internet connection. The displayed contained maximum speed and force parameter values that simplified by OpenHAB mobile apps through the data shows on every time the athlete do the high jump.

4. Results & Analysis

In this section, results obtained for both at the system and respondent levels are highlighted. It covers:

i. mechanical part of the prototype;
ii. programming of the wearable device;
iii. wearable device setup; and
iv. output and analysis.

4.1 Mechanical part

To realise this study, mechanical part for the wearable device has been firstly designed using Google SketchUp software as shown in Fig. 3 To make it as portable as possible, the device had been attached at the waist part for speed sensor node and the other one at the ankle part for the FSR sensor node. Fig. 4 shows a final version of the device with the size of 66mm × 56mm × 41mm.

4.2 Programming

In terms of programming, three (3) elements of programming involved – to send and receive the data wirelessly, to design the GUI and to deploy the functionality of the device via ESP8266. There were two (2) main code have been developed for overall, the subscribe data from ESP8266 and the publish data to mobile app.

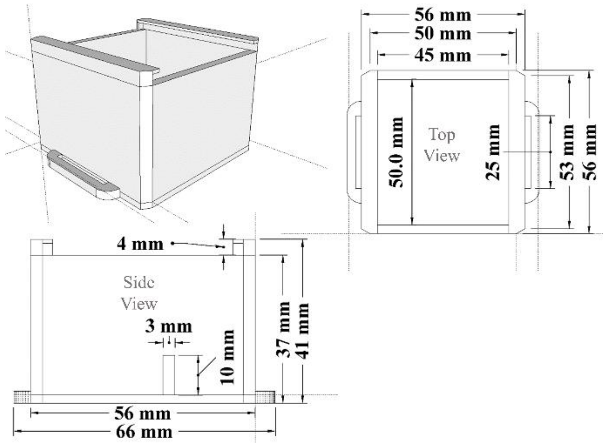

Fig. 3 Final version designed by using Google SketchUp software.

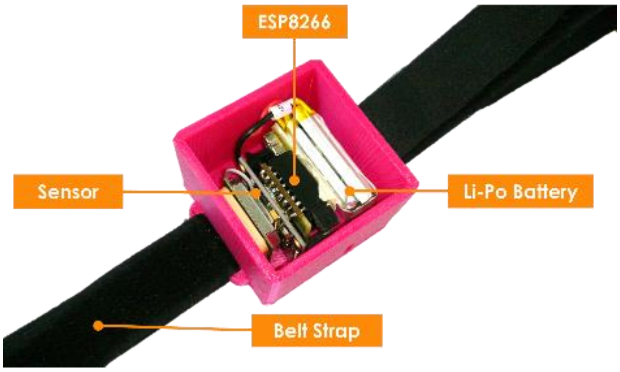

Fig. 4 Final version of the wearable device.

4.3 Device Setup

To test the functionality of the wearable device, the following steps are required:

i. GPS sensor was calibrated and compared with smartphone that have GPS to check the speed of the devices in steady-state and motion-state as shown in Fig. 5 (a);
ii. FSR sensor was calibrated using digital force gauge meter and compared with the data received via the mobile app to check the force of the sensor with and without force as shown in Fig. 5 (b);
iii. athlete need to stay in steady-state before start to run at approach speed stage; and
iv. speed and force input data were taken from the approach speed, take-off and land, in comparison with the benchmark (professional athlete) data and the data were recorded for every second.

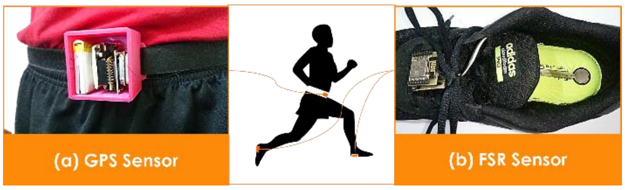

Fig. 5 Sensors configuration at waist and ankles.

To establish the concept of high-performance and low-injury as well as to accomplish initial feedback from professional athlete during the focus group on their expectation of the system, overall display has been added with various sections as depicted in Fig. 6. The first section consists of switch that require the athlete to press to start before the run and press stop after the jump. The second section is sensors part, these is where maximum speed of the athlete during the run and maximum force exerted at the ankle during the jump were captured in between the start and stop switch period of time. The last section is the logs part, it stores the data of athlete and show the history of maximum speed and force at certain date and time. Hence, it consists of a real-time input of speed and force data capture for waist and ankle movement compared with the reference data by professional.

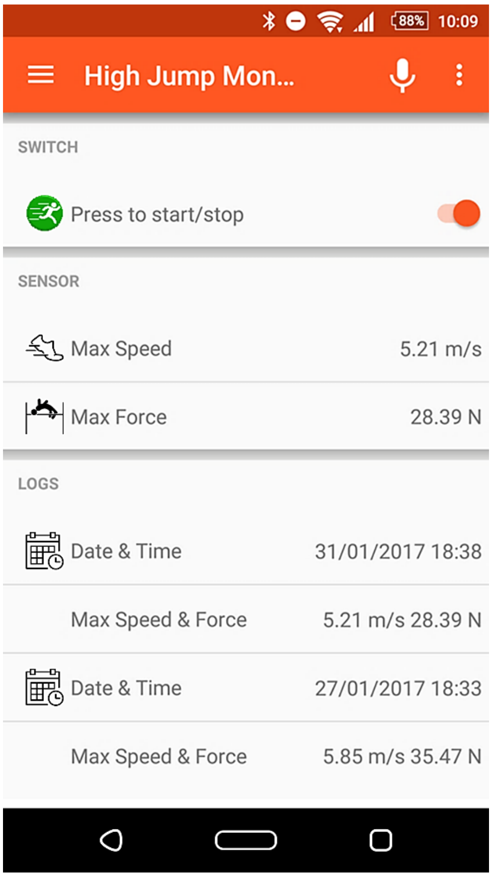

Fig. 6 Screenshot of main mobile app GUI.

To minimise injury, during training each athlete will be able to have a guide by referring to the benchmark data by the professional athlete that have been initially stored. With this comparison, the intermediate athlete will be always required to control the speed to reduce the major injury at the ankle as well as technique until they manage to achieve relatively almost similar speed with the benchmark data. It is expected, they will start to adjust their skills to control the speed and gain a great force and later better skills and performance will be achieved with new maximum height of the jump.

On the contrary to the current device, there is no real-time data captured and athlete were at risk as they only struggle on the performance. With the benchmark data, it shows that this proposed device concerns with injury and more significantly it can also educate athletes to execute self-assessment during their training. An example of results obtained for intermediate athlete compared with the professional benchmark data that had been achieved during experimented are illustrated in Fig. 7.

As seen in the graph, result shows that, the intermediate athlete need to run a little bit faster to increase the force exerted at the ankle, by then it can achieve the same or better result of the professional benchmark. With this device, it can tell the athlete either to run faster or slower depending on the result. Thus, this shows that the implementation of wearable device that uses speed and force parameter to prevent the injury at the ankle of the leg help a lot to increase the performance of the athlete by following professional benchmark data.

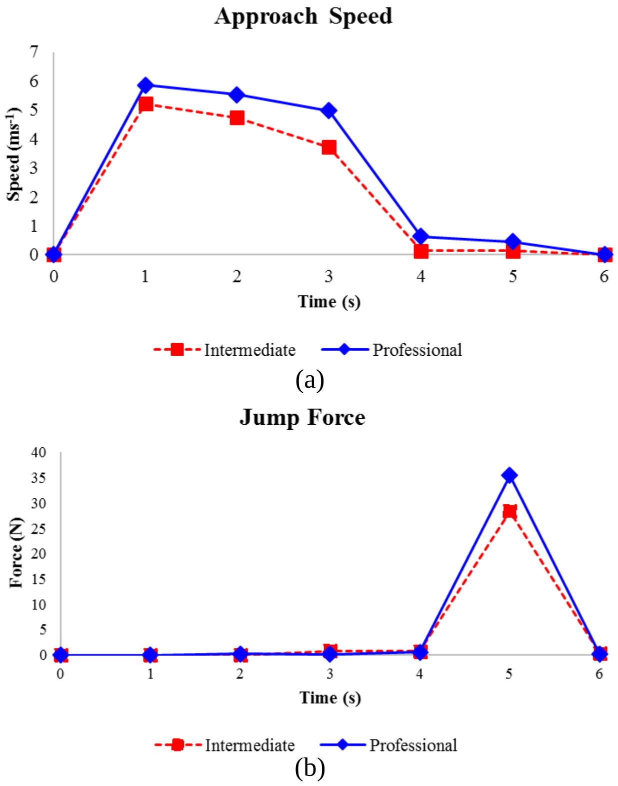

Fig. 7 Comparison of real-time data for (a) approach speed and (b) jump force movement between professional and intermediate.

5. Conclusions & Future Work

This paper presented the design and implementation of high-performance and low-injury real-time high jump wearable device by using ESP8266 microcontroller. The proposed device was successfully satisfying high jumpers' requirement, to have a wearable device that capable to visualise the data of training, assisting them to monitor their performance and minimise their injury with the availability of benchmark data. They can also retrieve the data of training and therefore capable to educate them during the training session.

To improve this work, future works concerning the design of the more compact wearable device with combination of popular sport mobile apps will be made for the better experience of training. Finally, this work bridges the gap between two (2) distinctive fields: sports science and engineering. Embedded systems and instrumentation that involves sensors and electronic components also contribute a significant role in advancing sports to another horizon!

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