Medical Assistant System for Athletes' Health Analysis Based on EMG-Signals Activity and Virtual Instruments as a Step towards the Internet of Medical Things

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Abstract

Monitoring and analyzing athletes' jumps system using Electromyography (EMG) signals based on Virtual Instruments (LabVIEW) is presented in this paper. This system was prototyped using the virtual instrument workbench (LabVIEW) to display the jumping pattern. In Jump analysis hardware (JA-H/W), there are sensory boards, ultrasonics, and wireless communication systems. To measure the minimum foot clearance (MFC) and orientation, there have been two types of systems used to simulate Jump Analysis Software Ultrasonic (JAS-UltSnc) as well as Inertial Measurement Unit (JAS-IntMeUnt). Combining JAS-UltSnc with JAS-IntMeUnt provided a complete solution with error correction. LabVIEW is used to display the jump patterns generated by the system and analyze the jump patterns of the athlete.

Keywords: Graphic Programming Language (G-Programming); Virtual Instrument Workbench (LabVIEW); Jumps Analysis System (JAS); Jump Analysis Software Ultrasonic (JAS-UltSnc); Inertial Measurement Unit (JAS-IntMeUnt)

1. Introduction

A programming environment called LabVIEW (Virtual Instrument Workbench) is used to create applications using G-programming [1]. Internet of Things (IoT) is the interconnecting of everyday objects with computing devices that transfer data over the Internet. Almost every aspect of people's lives is now connected to the Internet of Things, including medical treatment, which benefits both physicians and Athlete, and patients. Exercise reduces muscles' power-generating capacity, resulting in muscle fatigue [2]. There is a direct link between muscle fatigue and muscular strength, as observed in sports. The benefits of massage include improving local blood circulation, enhancing nutrition, and accelerating the discharge of lactic acid [3]. Identifying and evaluating muscle tiredness, a topic of practical importance in everyday situations, is receiving a lot of attention in research because it frequently happens in daily activities [4].

The majority of athletes experiencing muscle tiredness struggle with daily exercises, and over 50% have trouble with walking. Rehabilitation will be challenging once the athlete can no longer walk due to muscle fatigue. Continuous and precise monitoring is essential at rehabilitation facilities. LabVIEW helps athletes to speed up their recovery process while undergoing rehabilitation. Recognized for its functionality and broad use, LabVIEW is a widely adopted and standard software in the industry. Block diagrams and frontal views are both categories of LabVIEW graphical user interfaces (GUIs). Front-facing pages display buttons and additional controls. Each button on the page has a corresponding block diagram. Block diagrams illustrating dataflow execution order are utilized in LabVIEW for establishing program execution sequence, with functions depicted graphically on the front

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panel. A visual representation, known as a block diagram, displays the operations that manage the items displayed on the front panel. As per the block diagram, all the objects on the front panel are referred to as terminals. The terminals illustrated in the diagram can be viewed as either controlling data or indicating data. The terminal links the graphical portrayal of a function with transmitting data. While the program is running, the block diagram is not visible and only the front panel is displayed. User inputs and outputs are shown on the front panel controls and indicators. The controlled object manipulates input data from an instrument, while the indicator object displays the output data.

Recent paper was designed as follows; Section 1, introduce the general Introduction. Related Works presented in the Section 2. Based on Section 3, the system objectives was described. TheSystem Methodology and System Components were introduced in Section 4. In section 5, a Filter Design was descripted. Effectiveness and stability of the systemd introduced in Section 6. Finally, Section 7, include Results and Discussion.

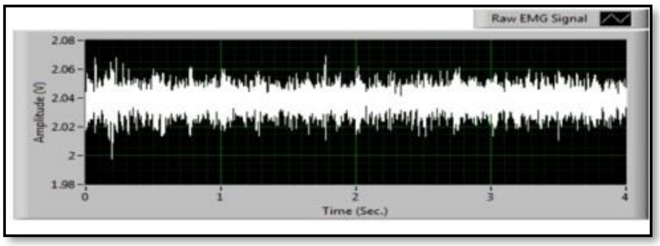

Figure 1. Front panel of LabVIEW Platform to Raw EMG Signal Acquiring

2. Related Works

D. Tkach investigated the durability of time domain through examination of sEMG pattern recognition and subsequently obtained frequency domain and traits to enhance assessment of muscle fatigue. Similarly, Wang Kui [7] examined muscle fatigue in the domains of frequency, time, and time-frequency. The system combines the ARM microcontroller core and AgCl surface electrode to successfully detect sEMG signals. The muscle fatigue detecting system now includes an MCU for the first time, but its complex hardware and operational complexity make it less effective for clinical use, despite offering a good baseline signal for research. At 2011, Wan Sha developed a system of multichannel sEMG detection. Despite being a substantial upgrade from previous technologies, LabView still experienced notable delays when switching between channels due to its real-time acquisition and visualization of sEMG signals on a PC. Not long ago, Zhu Anyang introduced an sEMG acquisition system based on STM32, which utilized a USB connection to transfer sEMG data to the host computer for analysis and processing. Even though all the previously mentioned sEMG signal detection systems were groundbreaking when first introduced, none of them includes smart terminals, greatly restricting their practical applicability. The EMG and ECG Richer created in 2014 could be used on Android smartphones to monitor cyclists' heart rate and rhythm immediately. A sEMG monitoring tool introduced by Widasari [12] enables individuals to detect muscle exhaustion before it occurs. A portable sEMG monitoring device created by Yamaguchi [13] detects bruxism by analyzing a masseter sEMG signal and alerting the user. Although these systems integrate sEMG monitoring with wearable technology, they primarily concentrate on a specific, individual purpose. This report describes a new system that detects and treats muscle fatigue by combining features from past systems into a user-friendly IoT system, merging sEMG signal detection with muscle fatigue relief methods. The myoelectric sensor collects sEMG signals and converts them into a digital signal with ESP 8266 technology. Using the digital signal, a vibrating motor is triggered to help reduce muscle fatigue. A user-friendly app can manage the device's vibration and monitoring functions by switching them on and off.

3. System Objective

This study aims to capture the jumping patterns and foot movements of the athletes during jumps. By identifying weakness in the pattern, the doctor can improve the athlete's condition. Toe-off point, minimum foot clearance, and foot clearance are the parameters taken into account. Sensor boards will transmit data wirelessly to the database as soon as they are powered on, and a real-time jump pattern graph will be displayed as soon as the board is powered on. JAS is used to display the graph.

The chart illustrates the height above the ground in feet over time. This graph can help in determining the least foot space required and the moment of toe lift-off. To enhance data collection accuracy, different patterns of toe-off and minimum foot clearance, MFC, were evaluated [14][15]. Users are able to adjust the parameters displayed in the software to suit their requirements. Strip charts, scope charts, and sweep charts are three distinct types of patterns, resembling paper strip chart recorders, oscilloscope displays, and electrocardiography displays, respectively. Millimeter measurements can also be used to inspect clearance readings [16].

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4. System Methodology and Components

There are a number of components in the setup, including a power supply, an EMG sensor, an IR sensor, an ESP8266 Wi-Fi module, vibration motors, and a motor driver module. Motor drive modules control vibration motors. As the main controller and Wi-Fi transmitter/receiver, the ESP8266 wireless Wi-Fi module manages sensor data and sends signals efficiently and effectively.

An infrared sensor can detect infrared signals to determine if the system is being used. The power source produces positive and negative DC outputs of 3.3 V, 5 V, and 12 V. When the muscle is activated, an EMG transducer measures the electrical potential and produces an EMG pulse. Data collected from the sensor is exclusively managed by the ESP8266. Based on the digital value representing muscle activation level, the vibration motor can switch between three gears. It emulates a wireless access point for communication purposes by operating in soft AP mode. With the mobile app, you can connect to the Wi-Fi module's hotspot. Through socket pairing, we send data using the TCP/IP protocol suite. Figure 1 shows how hardware components are represented and connected in the general layout of the system. IoT devices can be classified into three tiers based on the overall structure. By adapting to the user's preferences, a system was created to provide real-time muscle information. Three essential components make up the Internet of Things: a perception layer at the bottom, a networking layer in the middle, and an applications layer at the top. For each layer, Figure 2 shows the support provided by systems and middleware. An EMG transducer and an infrared transducer are included on the sensory level of the system. Through the network layer, the collected information is sent to smart mobile devices. The application layer analyzes and displays the data collected from the sensory layer. Regulation and supervision functions are available on the intelligent terminal.

Three varieties of JAS were utilized. The specifically created programs include JAS-Ultrasonic (JASUltSnc), JAS Inertial Measurement Unit (JASIntMeUnt), and JAS Integrated Combination of Ultrasonic and IntMeUnt (JASiCOM) [17].

JAS-UltSnc is dedicated to the ultrasonic technology used to measure the distance between the foot and the ground. Incorporating the ultrasonic measurement error algorithm will lead to a more accurate outcome for foot clearance. Micro-electro-mechanical systems sensors in JAS-IntMeUnt include both an accelerometer and a gyroscope to measure the jump's speed and orientation.

The MEMS sensors are an electronic device that gathers information on angular velocity and linear acceleration in a single unit, which is then transmitted to the main processor. IntMeUnt consists of two primary distinct sensors: an accelerometer and a gyroscope. This article introduced a new idea of combining JAS-UltSnc and JAS-IntMeUnt for creating jump analysis in rehab monitoring. Figure 1 illustrates the unit of shoe attachment that is controlled by JAS-iCOM software [19].

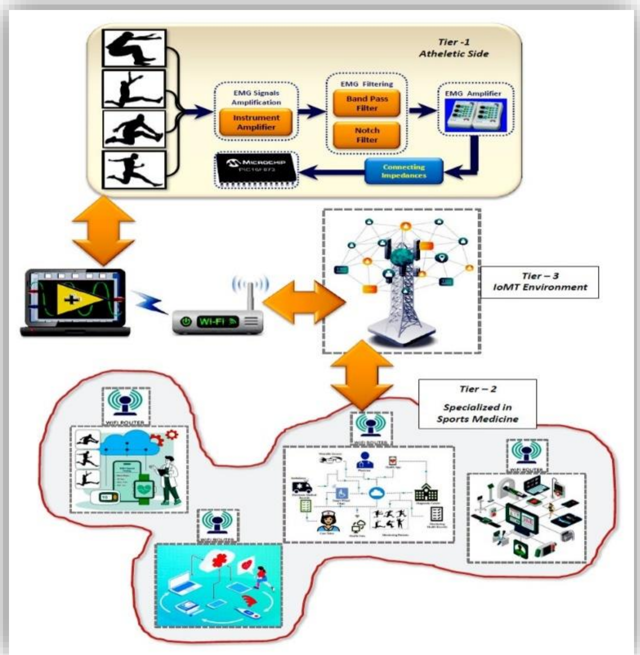

Figure 1. The proposed Methodology with 3 Tiers

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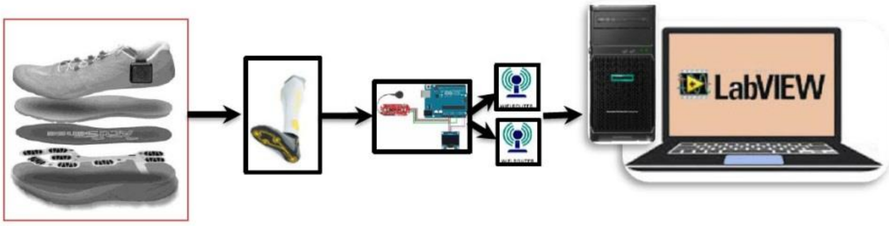

Figure 2. Shoe attachment unit for monitoring and analyzing Athletes' Jumps

The unit that is attached to the shoe to measure the speed of the jump is usually called a sensor, gyrometric device, or sports motion tracker. These devices can be:

- ***Accelerometers***: These small devices are attached to the shoe or the sole of the shoe, and are used to measure the speed and timing of jumps. They work by recording changes in acceleration when the athlete jumps or moves [20].
- ***3D Jump Analysis Systems***: These systems consist of units that are attached to the shoe, and are used to accurately measure the speed and direction of the jump by tracking movement in three dimensions. They may contain a combination of accelerometers and gyroscopes to measure angular velocity and time in the air [20][21].
- ***Smart Jump Devices***: Some smart devices, such as VERT or My Jump, that are attached to or placed near the shoe, are used to measure jump speed, height, and number of jumps. These devices are usually connected to smartphone apps to analyze performance [20[21].

4.1 D Jump Analysis Systems (3D-JAS)

3D-JAS are advanced technologies designed to analyze and measure the mechanics of jumping movements in three dimensions. These systems are commonly used in sports science, biomechanics, rehabilitation, and athletic training to provide detailed insights into an athlete's performance and movement patterns [22].

4.2 ESP8266 software development kit (SDK)

In general, there are two methods for utilizing ESP8266. The attention command can assist in choosing chip parameters and modes, requiring an additional MCU. In this scenario, ESP8266 connects with MCU via the serial port. This chip could also be utilized in the creation of a second official SDK for tasks like data transmission and sensor data processing. The ESP8266 chip features a 32-bit CPU with 80 - 160 K bytes of storage, along with on-chip processing capabilities that enable it to manage sensors and applications via GPIO. A flash drive can be directly used to initiate the ESP8266 chip if that is the only processor in the system. In this setup, the ESP8266 is programmed to function autonomously in the second mode. Due to the system's design, the circuitry is straightforward, with a low-power control integrated into the PCB [24].

4.3 Jumps Analysis System (JAS)-Ultrasonic (UltSnc) (JAS-UltSnc)

JAS-UltSnc utilizes a shoe attachment device to present ultrasonic measurement findings in LabVIEW and is tailored for the development of Jump Analysis Hardware. The project utilized a compact sensor board that can be paired with any shoes that have Velcro straps. Attaching the board to the shoes enables it to function wirelessly using the 9V power source. Therefore, this system can be activated immediately [25].

4.4 Graphic Programming Language (G-Programming)

G Programming, commonly associated with National Instruments' LabVIEW, is a visual programming language predominantly utilized for data retrieval, controlling instruments, and automating industries. Below are a few important aspects of G-Programming:

Graphical Interface: Instead of writing text-based code, G-Programming uses a visual interface where users can drag and drop functional blocks to create programs.

- *Data Flow Model*: The execution of G code is based on the flow of data between nodes, making it intuitive for visualizing processes [26].
- *Built-in Functions*: It includes a variety of built-in functions for handling data, performing mathematical operations, and interacting with hardware.
- *Event-driven Programming*: G Programming supports event-driven programming, allowing users to respond to user inputs and other events seamlessly.
- *Real-time Applications*: It is widely used in applications that require real-time data processing and control, such as in laboratory experiments and industrial systems [27].

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Overall, G-Programming simplifies complex programming tasks, making it accessible to engineers and scientists who may not have extensive programming backgrounds.

4.5 System based on Ultrasound (US)

A lightweight wireless ultrasonic sensor (Nexonar miniTriplet Beacon, 44 g) was placed in a neoprene harness positioned between the two shoulder blades. Each participant had a stationary ultrasonic receiver placed 2.5 meters above ground at a 45° angle behind him or her. Calibrating the device according to the manufacturer's instructions resulted in a 0.1mm resolution. The jump height was determined by comparing the peak point reached while jumping to the average height within a two-second period of standing due to the sensor's 50 Hz coordinate precision [28].

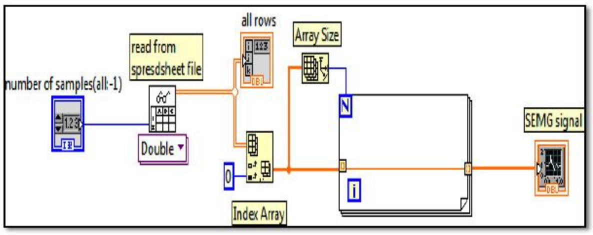

Figure 3. EMG Acquisition Data Circuit

5. Filter Design

The Butterworth filter was defined as a second order filter, with fNotch equal to 60 Hz and bandwidth equal to 10 Hz. In this circuit, R3 is used as a gain resistor to achieve a non-inverting pole-pair/zero circuit. Table 1 shows the values obtained for each component [3][29].

5.1 Amplifier

During this stage, the signal is amplified again after filtering out the noise signals so that the signal's amplitude is larger. With this approach, it is possible to process the data using a better quality level [11][14].

5.2 Graphical User Interface (GUI)

LabVIEW's visual interface is utilized to present a front panel where the EMG signal in Figure 4 can be viewed and saved. A LabVIEW program was created to retrieve data from the Bluetooth bee module through the serial port and store it for analysis of signals. The VISA - Virtual Instrument Software Architecture - LabVIEW offered serial communication [6][10].

5.3 Coupling Stage

An additional electrical voltage was introduced to the EMG signal before digitizing it. At this stage, it is not permissible to use negative values. An option to tackle this problem is by using an INA128P, which comes with a 2.5 V preset offset voltage [2][30].

5.4 Staging of Communication

An EMG system is connected to a Bluetooth Xbee V2.0 transmitter module with a data rate of 2.1 Mbps and a UART speed of 1 Mbps. A Bluetooth connection is used to demonstrate Nyquist's theorem. This enables the 5 kHz sampling of the EMG signal without oversampling after a 12-bit digital-analog converter has converted it. The frames were sent to a different Bluetooth device asynchronously and were subsequently handled using LabVIEW [30].

6. An Evaluation of the System's Efficiency and Stability

The accuracy and the time of response of the proposed system were not greatly affected by environmental factors, according to our research. It is evident from Tables 1 and 2 that the response time has been consistently kept within the range of 1 to 2 seconds. It demonstrated a consistent digital value change, successfully reducing muscle fatigue.

Experimental Athlete	Duration of the response in Second	Prior to use, digital value	Upon to use, digital value	Shift in Ratios
Athlete-1	1.0	619	216	3 →2
Athlete -2	1.6	618	211	3 →2
Athlete -3	1.2	615	194	3 →1

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Athlete -4	1.3	610	218	3 →2
Athlete -5	1.8	612	224	3 →2
Athlete -6	1.2	611	203	3 →2
Athlete -7	1.4	613	218	3 →2
Athlete -8	1.5	609	210	3 →2
Athlete -9	1.7	608	205	3 →2
Athlete -10	1.6	600	201	3 →2

Experimental Athlete	Duration of the response in Second	Prior to use, digital value	Upon to use, digital value	Shift in Ratios
Athlete-1	1.2	605	209	3 →2
Athlete -2	1.3	607	195	3 →1
Athlete -3	1.2	615	190	3 →1
Athlete -4	1.4	609	202	3 →2
Athlete -5	1.6	599	209	3 →2
Athlete -6	1.9	613	198	3 →1
Athlete -7	1.7	612	208	3 →2
Athlete -8	1.5	612	206	3 →2
Athlete -9	1.8	610	199	3 →1
Athlete -10	1.6	589	195	3 →1

6.1 JAS-IntMeUnt

The study discovered numerous mistakes in the jump measurement data, especially in the toe off and landing stages. Positioning the ultrasonic sensor at ground level and the vibrations it produces are factors that contribute to errors [11][18]. Therefore, the research suggests an innovation utilizing an IntMeUnt Sensor to address the inaccuracies in ultrasonic measurements. The process of obtaining IntMeUnt data mirrors that of gathering Ultrasonic data. This specialized JAS-IntMeUnt is specifically made for use with the Jump Analysis Hardware. Figure 4 displays the JAS-IntJump GUI and graphical results during athlete's jump [31].

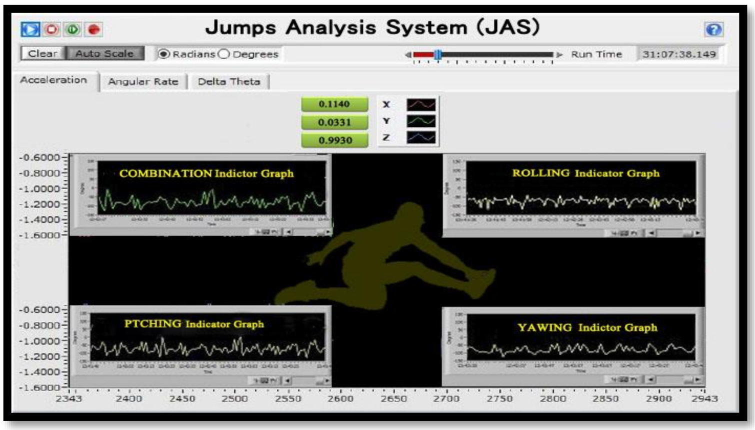

Figure 4. Analyzing Graphs: Hopping Movement with IntMeUnt Sensor excluding Ultrasonic Sensor (Graph showing Degree versus Time)

The IntMeUnt sensor produces roll, pitch, and yaw outputs. Data from rolling, pitching, and yawing is plotted together over time on a single graph. The ability to create distinct graphs is also taken into account to assist users in examining the jumping pattern based on individual orientation. At the same time, merged graphs allow users to analyze all three directions of the jumping pattern at once.

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7. Results and Discussion

7.1 Analysis of JAS-UltSnc

A diagram demonstrates the impact of foot clearance in millimeters on the jumping pattern. Data on MFC, toe-off and landing is obtained from foot clearance information. JAH/W is associated with the individual's shoes as they move around in their everyday tasks [32]. This experiment is being conducted outside of a lab to verify the real-world suitability of the system. The JAS-UltSnc System does not have the error correction algorithm feature.

[33].

Table 3: Technical specifications for JAS- UltSnc and JAS- IntMeUnt.

Method	Factors
JAS- UltSnc	Clearance of feet with ultrasonics
JAS- IntMeUnt	Orientation of rolling, yawing and pitching

The developed system shows the subject's jumping movements during running. The user interface displays various jump patterns, such as MFC, toe-off, and landing stages. Nevertheless, because of the inaccurate beginning point offset and the positioning of the feet at the time of the jump, the measurement is not exact. The JAS-US System measures distance directly instead of measuring foot clearance. Nonetheless, it also displays the system's ability to precisely record the subject's jumping movement during walking. The gathered series of jumps and information were obtained from JAS-UltSnc [35].

The system provides strong evidence that the JAS-UltSnc is suitable for measuring jump analysis.

7.2 Analysis of JAS-IntMeUnt System

The integration of JAH/W and JAS-IntMeUnt is done by the JAS-IntMeUnt system. Figure 5 demonstrates how the pedestrian utilizes the JAS-IntMeUnt System for jumping. IntMeUnt sensor data was used to evaluate the jumping pattern and compared to data from the JAS-IntMeUnt System during walking. This system also measures jumping technique based on foot clearance, as demonstrated by the JAS-IntMeUnt System. The JAH/W system is connected to a mounting unit and paired with the individual's footwear. The individual will be guided on a walk while carrying out their usual daily tasks [35].

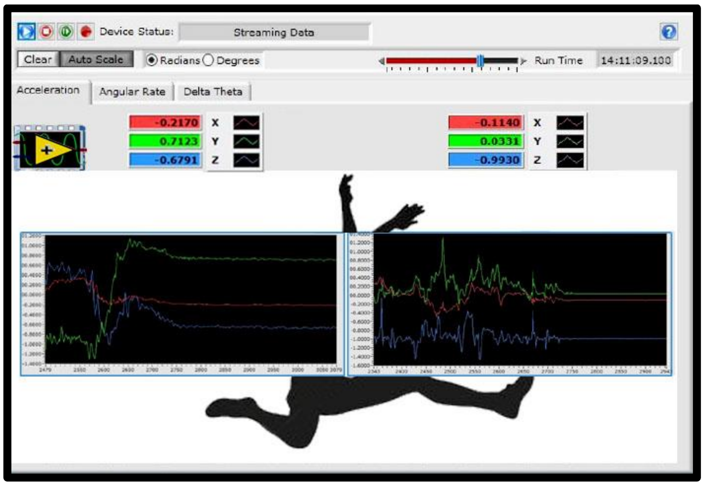

Figure 5. Display of kinematical data and analysis of EMG signals using LabView windows.

A high-quality laptop and an RS232 communication port are necessary for accessing sensor data and conducting calculations. LabVIEW, included in the system, offers necessary functions for configuring sensors and gathering data in graphical system design and development. LabVIEW, short for Laboratory Virtual Instrument Engineering Workbench, is a tool for creating and developing systems using a graphical programming language. LabVIEW is frequently used for tasks such as data acquisition, processing, instrument control, and industrial automation.

7.3 Analysis of JAS-Integrated Combination of UltSnc and IntMeUnt (JAS-iCOM)

The data collected by this system is more comprehensive than those collected by other research projects are. The system analyzes jump patterns based on gender, feet, age group, toe off stage, and MFC and landing phases based on foot clearance. Table 4 displays the information collected from a set of athletes. This system is connected to the shoe's mounting unit and attached to the athlete's footwear. The system's suitability for assisting in athlete

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rehabilitation is tested outdoors during the trial. This update introduces new methods for evaluating foot clearance errors, offering a fresh perspective and a major advancement in the field.

Table 2: An Experimental Athlete's Details

Testing of Athletics	Gender	Birthday	Height of the body	Weight of the body	Normal			Abnormal		
					Pitching	Rolingl	Yawing	Pitching	Rolingl	Yawing
Athlete-1	male	18	178	66	-18	-32	72	-13	-30	77
Athlete -2	male	20	175	68	-54	-8	65	-49	-6	70
Athlete -3	male	25	174	81	-110	-13	241	-105	-11	246
Athlete -4	male	30	173	76	-41	97	67	-36	99	72
Athlete -5	male	35	171	71	-59	-41	74	-54	-39	79
Athlete -6	male	38	175	70	-107	-67	225	-102	-65	230
Athlete -7	male	40	170	79	-80	-67	164	-75	-65	169
Athlete -8	male	45	173	76	-4	-47	119	1	-45	124
Athlete -9	male	50	170	72	-57	-76	347	-52	-74	352
Athlete -10	male	60	168	64	-110	-13	154	-105	-11	159

8. Conclusion

This article talks about developing a prototype for a system that analyzes Athlete Jumping for rehabilitation, using the LabVIEW software tool. Examining various JAS systems such as JAS-UltSnc, JAS-IntMeUnt, and JAS-iCOM indicates that LabVIEW software can effectively depict fast human motions. The data gathered in JAS-iCOM offers information that is more comprehensive compared to that of JAS-UltSnc and GAS-IntMeUnt, as indicated by the findings.

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