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Novel Sprinter Assistive Smart Agent for Continuous Performance Improvement

Hasitha Subhashana[1], Chathumi Bandara[1], Irushan Bandara[1], Anupama Devindi[1], Kuruwitaarachchi N[2] and Tharindu Dharmasena[1]

[1]Faculty of Computing, Sri Lanka Institute of Information Technology, Sri Lanka
[2]Faculty of Technology, University of Sri Jayewardenepura, Sri Lanka
E-mail: it17132138@my.sliit.lk, it17150408@my.sliit.lk, it17121866@my.sliit.lk, it171257588@my.sliit.lk, kuruwita@sjp.ac.lk, tharindu.d@sliit.lk

***Abstract:* — In the field of Sports, sprinting is the term used for introducing running over a short distance in a limited time. To date, a method to identify whether sprinters are getting enough speed during the accelerated period is not available so far. This paper proposes a smart agent to recognize the technical precision and performance of a sprinter using wireless hardware devices and a software solution. Smart shoe, track sensor, arm motion detection bracelet are the devices used to collect data from a sprinter. After required data collecting is complete the based web application provides feedback to the sprinter to improve sprinting techniques. This modern technology based system reduces human errors and workload of a trainer and would be highly beneficial for the sports community including coaches and sprinters as it could be accessed through mobile phones. The results of the study show the visualization of sprinter data effectively and an analysis on the obtained data regarding the performance.**

Index Terms—Smart Agent, Sprinter Assistant, Performance Monitoring, Automation.

I. INTRODUCTION

Multiple research projects prove the idea of running and sprinting are both movement intensives widely utilized in the field of Sports [16,17,18]. Even though both use the same muscles, the difference is, speed and the time. Sprinting is a more efficient, and quicker method of running that can only be achieved in short distances where the sprinter holds full speed through the whole race. Sufficient and qualified coaching staff should be considered as a primary concern in any sport, and it is also important to have good maintenance of necessary sporting equipment to practice with[1]. Runners start the race at the expert level by accepting a hunkering position in the beginning squares prior to continuing and moving upstanding continuously as the race advances and the energy gains. Depending on the start, the set-position is different. The use of starting blocks allows for increased isometric preloading by the Sprinter. A high force output that creates significant flight time and lower ground contact time will help achieve maximum sprinting speeds.

Analysis of human movement consists of observing and evaluating the three-dimensional movements over time of body parts. Many approaches have been utilized for this purpose, including video motion analysis and, recently, inertial sensors. Such mechanisms are expensive to implement, require fixed cameras, and suffer from occlusion in a controlled environment[2].

This paper presents a multiple hardware devices system that is working as an agent for sprinter assistant and used as a common platform to enable sprinters to collaborate to give better output of their performance. The agent has various other measurement capabilities to identify motions and movements of the sprinter during the practicing time. This paper only focuses on the motion identifications and the performance analysing part of the sprinter assistant system. The paper demonstrates the development and analysis of a sprinter assistant smart agent. In Section II, related work on similar sprinter performance detection systems is discussed. Section III enumerates the methodology used in approaching the solution, while the results and a discussion of the results are presented in Section IV. Finally, Section V presents the conclusions, and the future work.

II. RELATED WORK

Currently, there are some traditional approaches to detect the performance and accuracy of a sprinter. The availability of low-cost wearable inertial sensors[10], including accelerometers, gyroscopes, and magnetometers, has recently offered an alternative method of overcoming the drawbacks of motion capture mechanisms. According to[6,7,8,9] research projects, human motion tracking using Tri-Axis Inertial /Magnetic Sensors Package was widely adopted by implementing motion detecting devices.

Some research projects,[5,6] have designed methodologies to know about direction information which can be used to visualize and enhance the foot strike of sprinters. Researchers in[5] have reported mobile applications integrated for smart shoes, which are used to display power generating in a specific time. Some researchers indicated that the linear speed is still a major factor as to whether athletes succeed or not[3]. There are more devices available to get data about how a sprinter ends the sprint, but the accuracy of them cannot be guaranteed. Therefore, in track system devices, using the speed IR sensor wide range of movements of the sprinter can be detected for more accurate results[4].

Free Lap is a kind of hardware device that achieves sprinter overall speed[19]. In there, jump mat choice and target jailor knowledge assortment are used to investigate aspects of testing athletes and the lights on their temporal arrangement system square measure used for gross reaction and decision-making edges that the opposite systems. In the U.S. have a Brower timing system to get time[20]. The most common temporal arrangement system within the U.S. The system is single beam and needs plenty of set-up time if getting ready for multiple splits. The device connects to a smartphone, however, needs a transmitter link to try and do therefore.

III. METHODOLOGY

The cloud smart platform is centred around its main smart agent which includes multiple devices: Smart shoe, Arm motion detector, and Track sensor system. These devices house multiple sensors: MPU6050, Force Sensitive Resistor (FSR) sensors, and IR Sensor. The sensors are connected to a ESP32 board to collect data and transfer to the cloud database. The smart agent will directly communicate with the web application to capture the sprinter's motions and movements for identifying the correct and incorrect techniques.

The sprinter assistant agent can be used only during the practicing time of a sprinter assuming only one sprinter is on the track at the movement. The proposed system is designed to be easily interfaced with a sprinter when the practicing time. The Smart agent transfers the captured motions and movements to be processed to a local server which implements the correct sprinter techniques identification subsystem of the proposed cloud platform.

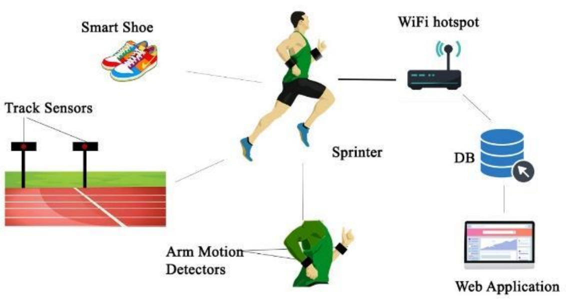

Figure 1: System overview diagram

The Smart assistant agent will capture the movements of the respective sprinter and identified records will be sent to the web application and display a proper graphical representation to visualize the correct and incorrect techniques used during the practicing time. The system will then inform the sprinter and coach about the point at which the sprinter dropped the proper technique and it will help to improve sprinter performance.

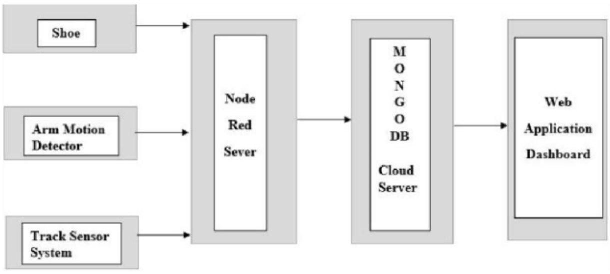

Figure 2: Sprinter Agent Controlling System

A .Cloud Platform

The MongoDB victimization database was developed for cloud storage. Many developers and researchers are doing their projects with MongoDB as needed to manage their data collections. With the help of those studies, authors would be able to add several different types of sensor data within this database. In an extremely natural, intuitive way, MongoDB makes it easy to store a variety of heterogeneous detector information and combine it with enterprise knowledge, enabling the incorporation of IoT apps around the organization. This information was created on the backend of the web page. To store all the sensor data of each device, this cloud storage was used with the idea of data security while accessing[18]. For the sensor data (MPU6050 data, IR sensor data, FSR sensor data are all sensor data) in each device, a table in the online database is allocated.

Besides, a graphical representation was generated using JavaScript for each collection in the online cloud storage. A connection is made between the sensors and the online cloud storage using the ESP32 board to directly insert sensor data into the cloud storage by attaching it directly through the hotspot. A Python Flask code was used on the database side to make the connection to the database through a URL. These sensor data were automatically uploaded to the cloud by coding the ESP32 board to connect to the Wi-Fi network and generating the online database URL.

B. Sprinter Agent Communication Network

Contact between the shoe and the bracelet with the track sensor system was generated to preserve optimum values in cases where the values vary from them. Thus, each device consisted of a ESP32 Wi-Fi and Bluetooth module that was used to create a communication medium between the devices in order to create a network. It is a cheap, reliable module with low-cost, low-power system on chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. Has various power modes and dynamic power scaling. Communication between ESP32s has been developed using MQTT (Message Queuing Telemetry Transport). MQTT is an ISO standard protocol for publish-subscribe-based messaging. It operates on top of the protocol for TCP/IP. The online broker acts as an intermediary and the messages (by smart agent) for a specific subject will be published and the messages will be received by actuators subscribed to the respective subject, thus establishing contact between smart agent networks. An interface was developed using Node Red to force control devices to display application data more clearly. All were connected to the Node Red interface using MQTT protocol, sensors and devices. Node Red nodes are subscribed to the specific topics for which the information is written.

C. Mechanism to Control the Actuators.

Conventional sprinters and coaches use human expertise to maintain sprinter technique analysis. It is essential to implement a sophisticated controlling mechanism that will provide a reliable, power conserving, and autonomous control system for the sprinter technique analysis. Usage of IMU(Inertial Measurement Unit) sensors is one of the most common approaches to fulfil the current requirement of implementing an efficient control system. Multiple devices embedded system was implemented to fulfil the motion capturing and decision making process as it is the most suitable application for a sprinter who is running on the track within a short time. The multiple devices embedded system developed within the project could be worn on sprinters' bodies to capture motions and movements. Sensors in sprinting track and sprinter's wearables. To gather sprinters' movements of arms, an arm motion detecting bracelet is developed. Then to detect foot strike patterns, and movements of lower limb a smart shoe is developed. Finally to identify the performance of the sprinter in relevant points a track sensor system is implemented.

- Smart shoe: When implementing smart-shoe, researchers have to include three FSR sensors, but implementing with three sensors, need to use multiplexer to solve integration between these sensors that needs to increase the analog pins in the ESP32 board. When fixing FSR sensors into the smart shoe, three FSR sensors are used according to the forefoot, midfoot, and rare foot areas separately. Those sensors have been fixed inside the shoe stole, and it has covered the rubber protection layer. It helps to prevent the damage of sensors. Fixing sensors like this, it may get more accurate patterns for each foot strike. Every time a sprinter's foot bends while he/she was running on the track. FSR sensors are very thin and flexible; therefore, if the Sprinter's foot bends while running, it does not impact the sensors.

To identify the angle of the sprinter's lower limb motions and movements MPU6050 sensor is also used in the smart shoe. These sensors are connected with ESP32 to communicate with the sensors. Those sensors are mounted in pairs of shoes and check the value of each of them. Because even minor vibration is not produced by the lower limb motion detection components due to device vibration, it is not important to calibrate values to mitigate vibration noise. However, the MPU6050 values were successfully adjusted according to the exact location of the sensor position of the lower limb motion detector.

- Arm motion detection bracelet: The MPU6050 accelerometer and gyroscope sensors were used to gather raw data from the sprinter's arms. This sensor is attached to a ESP32 and it is integrated with the arm motion-detecting bracelets. Before the sprinter starts to run on the track sprinter should power on the arm motion detecting bracelets. Before the sprinter begins running on the track, the sprinter must power the bracelets to detect arm motion. It will be connected to a Wi-Fi hotspot after turning the bracelets on. This can be the hotspot of the sprinter or the coach's cell phone or tablet PC. Wi-Fi hotspot passwords should be activated sooner. By using the raw values of MPU6050, calculated angle and, getting time by using NTPClient library.
  PubSubClient library is used here to provide a client for doing simple publish/subscribe messaging with a server that supports MQTT.

- Track sensor system: A modified timing system is developed by using a sharp IR Sensor and NodeMcu ESP8266(Measurement sensor is IR). Then transmit the data within each one. This measurement sensor is aware of Ultraviolet (UV) and sound. And it can be covered only by heavy detection like human detection. The human notion is triggered using sharp IR sensors. There are 4 sharp IR sensors mounted into each device as one per each. Using the ESPwifi module the real-time can be obtained by the internet when movement is triggered. When each of devices are triggered it gets the internet date and time when it connects to the Wi-Fi.

D. Method of Navigation

During the smart agent navigation, multiple devices should move to the given goal by using the current state, information from the environment, goal position, and a set of predefined actions. Predefined techniques and their respective count of records within one sprint are listed in Table I.

Table I: Sprinting techniques used in smart Agent

Type of technique	Count of sprint within one sprint
Leg motions	1000+ records
Arm motions	150 - 200 records
Stride patterns	30 – 40 records
Timepoints	4 records

The sprinter assistant agent identifies the technique which they have implemented for (Leg motions, Arm motions, Stride patterns, Timepoints), in the running track during the running.

After triggering the data all pressure sensors data and MPU6050 data will be filtered between start time and end time by getting track sensor systems. After that send them to the node-red server. When after the first triggering on the start point of the timing system, the server identifies the race is started and starts to gather relevant data from shoe and arm motion detectors. And wherever the timing system sends the end time of the race it will automatically stop transferring data to the node-red server. Node-red sends CSV files from each device to the web application.

Web application generates graphs using CSV files and sends JSON[12] files to MongoDB[13] cloud server. The node-red server can be used to create CSV files as a large amount of data is received from the MPU6050 and FSR sensors. Therefore, there might be data traffic with the devices, and it may affect the accuracy of output data.

Furthermore, the next step is to show the sprinter performance by comparing the data set of well-performing sprinters with current data in web application. One algorithm will be used to analyse data of arm motion detectors and lower limb motion. To get the speed of the sprinter, the following equation can be used, **speed=distance/time.**

Table II: Device results for one lap

Standard time on each point	Speed and angle should be maintained (Speed, arm angle, leg angle, stride pattern)	Results from the relevant device (Speed, arm angle, leg angle, stride pattern)
0m – 0s	0,90,90,forefoot	0,90,90,forefoot
40m - 4.90s - 5.81s	7.745,90,120,forefoot	8.11,85.88,125,forefoot
70m - 5.83s	11.99,90,120,forefoot	12.05,90,130,forefoot
100m – 13s – 14s	7.415,90,120,forefoot	6.00,85,120,forefoot

And, then data will be analysed with a well performing sprinter. When external behaviour is incorrect, it is hard to identify the movement of the sprinter. According to world-class sprinters, then below 10 seconds may be a smart 100m time[14]. If it is for a high school sprinter, then below 12 seconds may be a blast. Currently, authors are mainly focusing on high school sprinters. Therefore below output data in Table II is matching with them.

IV. RESULTS AND DISCUSSION

This study ultimately proposed a solution successfully to the problem of detecting the performance and accuracy of a sprinter while running and a novel solution to a smart approach is introduced. The shape of the curve could mirror the sprinter needs to maintain high sprint velocities. so, the velocity distance relationship is also better than the distance time relationship once estimating sprint coaching times.

Table II shows the sprinter time evaluation of each distance. This result output describes the time with the date. Analysing the speed of the sprinter according to the above data will be done. And it will be shown below in Table III In there are various speeds of each point. There is a little bit of deceleration until 40m and then he maintains high acceleration from 40-70m. From the 40m he started to increase his speed and he reached to 40m within five seconds. Then the sprinter maintains maximum velocity until 70m within a maximum of 3 second. Therefore, have decided to get sprinting times on each point as well. And after 70m the sprinter maintains a deceleration period within 6 seconds.

Table III: Example of target times and velocity

Target distance (m)	Target time range(s)	Equation for velocity range(m/s)	Target Velocity (m/s) from v = d / t
40	4.90-5.81	(40/4.90 - 40/5.81)	8.61-6.88
70	5.83	(70/5.83)	11.99
100	13-14	(100/13 - 100/14)	7.69-7.14

Through the beginning time and end time, all other devices' data will be generated accordingly. The curve below Figure 3 shows the motion of the arm during the sprinting. There are seven records(motion) in this diagram and the red colour patch in the pie chart shows the incorrect movement of the arm. If the sprinter keeps his arm less than degree of 80; it shows the wrong movement with red colour. And the green colour patch shows the correct arm motion of the sprinter. In the first two points, he has got an angle below 80's degree, and then he maintained correct arm motion with more than 90's degree.

Figure 3: Arm motion during sprinting

The graph in Figure 4 shows the foot strike pattern of the sprinter. The green colour line shows the forefoot strike, the yellow colour line shows the midfoot strike and the red colour line shows the barefoot strike in the chart. It shows a summarization of the foot strike using a pie chart as well. In this research, generate only a midfoot strike and rearfoot strike in the pie chart as highly affect the sprinter's performance.

Figure 4: Foot stride during sprinting

The curve below Figure 5 shows the motion of the lower limb during the sprinting. There are seven data (motion) in this diagram and the red colour patch in the pie chart shows the incorrect movement of the lower limb. If the sprinter keeps his lower limb less than 120's degrees; it shows a wrong movement with red colour. And the green colour patch shows the correct lower limb motion of the sprinter. In the first two points, he has got an angle below 120's degree, and then he maintained correct lower limb motion with more than 120's degree.

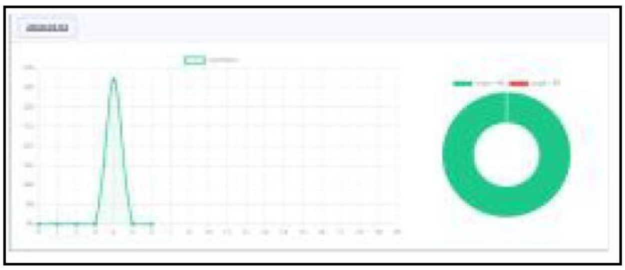

Figure 5: lower limb motion during sprinting.

V. Conclusion And Future Work

A fully autonomous system to identify sprinter performance, with cloud storage for raw data, multiple hardware devices as data collectors, and a web application to visualize the sprinter's performance was implemented. Hardware devices are used to extract necessary data from the sprinter's arm, lower limb, foot, and performance on the track. Further, devices in this Smart Agent network consist of automated navigation in order to avoid obstacles. Node-red was used to send CSV files from each device to the web application. JSON arrays are used to send data to a MongoDB cloud server from the web application. This research has mainly focused on identifying incorrect patterns of sprinters by introducing the prototypes of lower limb motions and strike pattern detecting smart shoe, arm motion detection bracelets and track system for getting time on desired points. Future more can suggest well-implemented devices rather than prototypes and can consider the prediction of the data set as well.

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