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IoT Based Football Player Training Session Simulation

Baydaa M. Merzah[1], Muayad S. Croock[2], Ahmed N. Rashid[3]
[1]*Computer Science Department, College of Computer Science and Information Technology, University of Anbar, Iraq*
[2]*Control and System Departments, University of Technology, Baghdad, Iraq*
[3]*Department of Computer Networks Systems, College of Computer Science and Information Technology University of Anbar, Iraq*
[1]*bai21c1007@uoanbar.edu.iq*, [2]*muayad.s.croock@uotechnology.edu.iq*, [3]*rashidisgr@uoanbar.edu.iq*

Abstract— *Simulation software is considered as an important step in the development of internet of things (IoT) scenarios and has been the subject of intense research in the past decade. While most previous efforts in simulating these devices have focused on the communication protocols and the sensor node layers issues, a significant aspect remains in precisely measuring some health metrics of football players. Some of the IoT technologies are allowed to be used during the real match or training practice, while most of them were forbidden by the Fédération Internationale de Football Association (FIFA). One promising aspect, is to simulate the health metrics of the players during the training session using the concept of wireless sensor nodes with integrated sensors. The available simulation programs do not support all the required features in the football field. For that, in this paper the TrainPlayer is presented, a health level sensor network simulator which collects the required metrics for the players nodes and can send the data payload using the Message Queuing Telemetry Transport (MQTT) protocol. It developed by utilizing the object-oriented programming features and the graphical user interface in python libraries. The work simulates the movement of the player on the pitch and how the metrics are generated, collected and sent to the server. The collected data is varied during the exercises. This monitoring system helps the coaches to fix the training workload by the team trainer or coach to reach the optimal fitness level. The results show the reliability of the MQTT protocol in message delivery and the acceptable delay time. TrainPlayer's ability to measure detailed metrics can shed new light on design proper training workload for each player. In the future, the software can be enhanced with additional features to become a complete tool for simulating football players.*

Index Terms— *Football player, IoT, MQTT, Simulation tool, Training.*

I. INTRODUCTION

In paradigm known as the internet of things (IoT), many technologies are brought together to create a system that connects the digital and physical worlds. These technologies include computers, the internet, sensors networks, communication technology, and embedded systems. The Internet of Things (IoT) is attracting interest from many different sectors because of its status as a promising future technology topic. There are a lot of various kinds of devices and smart items that are currently communicating with each other through the internet protocol. The proliferation of smart gadgets suggests that the internet of things will soon have far-reaching consequences for people's daily lives [1].

In the sport field and in specific the football, the IoT technologies is widely used in the last decade. Internet-connected sensors and equipment that collect data from the pitch and players have facilitated

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real-time integrated analysis. Players utilize sensors and equipment to quantify heart rate, running speed, distance traversed, muscle activity, and various other parameters to assess their performance levels. Devices can also be integrated into smartwatches [2], bracelets [3], or vests [4]. These sensors are linked to a remote server to facilitate the monitoring of data streams by the teams. The data gathered by these sensors and gadgets can be utilized to create customized training programs that target certain shortcomings. Coaches can monitor player performance in real time throughout matches to facilitate strategic substitutions [5]. The wearables for tracking footballer performance are diverse, featuring various sensors and designs. For several reasons, including scalability evaluation, developing and validation, and economic development, simulators are essential in the design, implementation, testing, and research of the (IoT). The IoT has grown into a significant technology that allows devices and systems in many different industries to communicate with one another, including smart cities, healthcare, agriculture, and manufacturing [6].

Many important science and engineering fields use simulation tools because it helps to solve problems before they arise. The most advanced technique for analyzing process behavior, risks, and complex systems with their inherent uncertainties is simulation, particularly process simulation. Simulation is a valuable tool for training support since it offers insights into project and process designs before a large amount of time and money has been spent. Research from different fields may benefit greatly from the methodical fusion of simulation techniques and empirical data [7].

By enabling items to be uniquely recognized and enabling computers to control, track, and monitor them, the IoT created a global environment. Items possess the potential to self-configure using a common communication protocol such as the Constrained Application Protocol (CoAP) and Message Queuing Telemetry Transport (MQTT). The MQTT protocol [8] is applicable in a number of environments such as home automation application [9], health care [10], smart cities [11] and sport [12]. It is a lightweight, simple to use, and low bandwidth for billions of smart items. Publisher, server, and subscribers make up the MQTT as it appeared in *Fig. 1* MQTT broker and publish subscriber principle [13].

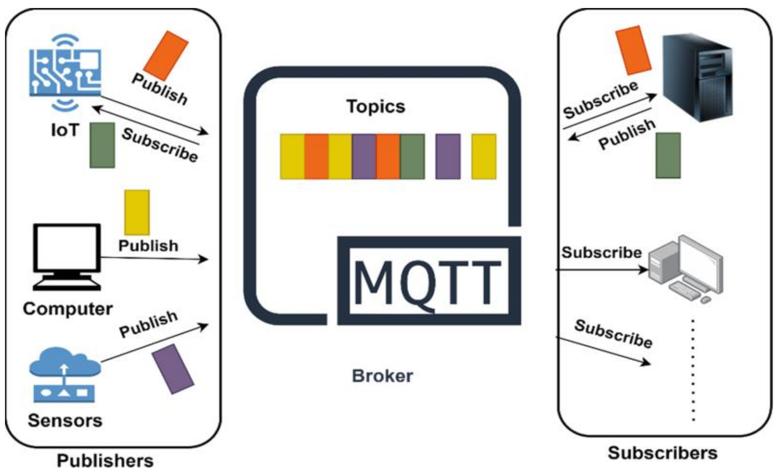

FIG. 1. MQTT WORKING SCHEME.

Since the IoT approach is a fresh topic in the sport industry, it has some specifications in using the available simulation software. Many simulation tools are available to be used in the academic sector but they couldn’t support the different scenarios, as illustrated in the next section. Therefore, this work developed a TrainPlayer to simulate the football players health metrics performance during the training session. The players represented as wireless sensor nodes with four different sensors (Heart rate, Oxygen level, Steps and body energy). The MQTT is used as a communication protocol to send data

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from the players during the training to the broker. The data is received as csv and text file for further analysis by the team coach or the trainer.

This paper is organized as the following: in section II is the literature review, the fitness metrics adopted in this work are explained in section III. While the design of the proposed simulator is illustrated in section IV. Section V present the actual test and discuss the results. The last section is the conclusion of the work and the future plane.

II. LITERATURE REVIEW

In the field of wireless sensor networks, there are different available tools some are cost free for academic use, while the others are commercial or a task specific software. In this section, the widely used wireless sensor network simulation tools will be discussed with their limitation if available.

OMNeT++ is a free software general-purpose simulator that utilizes the C++ programming language for the building of simulation models. The OMNeT++ paradigm for their simulator comprises a series of hierarchically structured components. The highest-level module is referred to as the Network Module. It offers comprehensive GUI support and an embeddable simulation kernel for displaying user interactions [14]. The interactions among modules are documented in a log file. The drawbacks of OMNeT++ are: the integration of separate models is intricate and may lead to significant issues. Furthermore, in contrast to other simulation tools, OMNeT++ does not offer a comprehensive library of pre-constructed models specifically designed for wireless sensor networks (WSNs). Consequently, developers frequently must construct their models from the ground up or modify existing models to meet their particular needs, a process that can be labor-intensive [15].

NETWORK SIMULATOR-2 (NS-2) is now a prominent network simulator frequently utilized in both academic and business environments. It provides substantial assistance for simulating routing and multicast protocols across both wired and wireless networks, organized in either a structured or unstructured manner. NS-2 comprises Object-oriented Tool Command Language (OTcl) and C++ [16]. NS does not furnish graphical representations of the data generated by simulations. Raw data must be processed via programming languages. The primary drawback of NS-2 is its lack of user-friendliness due to its text-based interface; numerous researchers have expressed their discontent with the intricate learning curve associated with NS-2.

MATLAB Simulink, a crucial software component, serves as a backend support system for MATLAB. Simulink is capable of modeling both non-linear and linear systems in continuous time, sampled time, or a hybrid of the two approaches. Simulink provides a graphical interface for building block diagrams, together with drag-and-drop capability for creating both diagrams and their components [17]. This is a commercial software, and acquiring licenses can be expensive, particularly for independent researchers. The cost issue must be taken into account when selecting a simulation tool, particularly if budget constraints are present. It is extensively utilized for WSN simulations; yet, it lacks dedicated features or models specifically tailored for WSNs.

NETSIM is an additional network simulation tool. It is a stochastic discrete event simulator that rapidly garnered significant attention owing to its distinctive attributes and extensive simulation library support [18]. It is offered in three versions: Academic, Standard, and Pro. In comparison to widely utilized simulators such as NS-2 or OMNeT++, the community support and resource availability for NetSim may be constrained.

Criteria to select the simulation tool is illustrated in Table I.

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TABLE I. SELECTION CRITERIA

Tool	OS	Mobility	Dynamic events visualization	Health sensors	MQTT protocol
OMNeT ++	Windows/Linux	✓	✓		
NS2	Linux	✓	✓		
MATLAB	Windows/Linux	✓	✓	✓	✓
NETSIM	Windows	✓	✓		
TrainPlayer	Windows	✓	✓	✓	✓

Based on the simulation tools discussed in this section and the task specific selection criteria, it is obvious that the available tools don't compatible with the task of this work. This task needs to represent the player as a mobile wireless sensor node in the IoT environment, each node has an integrated health metric sensor (Hear Rate, Oxygen level, Steps count and Energy level) and able to send the sensing data to a local base station in the playing field. The basic required functionalities are missing in the traditional wireless sensor network simulation tools, since they deal with the network concepts such as the topology, routing protocols, OSI layers and the physical connection types. Thus, this work proposed to design and develop a task specific simulation tool to cover all the required metrics. The contributions of this work are:

- Design and develop the Train Player simulation tool.
- Train Player is a novel footballer training performance monitoring simulation tool.

III. THE FITNESS METRICS

The emergence of the Internet of Things (IoT) has allowed coaches and athletes in the sports industry, particularly in football, to strategically improve their players' training and game, giving them a competitive edge. Athletes can now monitor their development and track their performance with a range of tools, gadgets, and mobile applications. The smart sports sector offers a fresh perspective with enormous promise for efficient decision-making services [19]. Many important health and physical performance metrics affect the performance levels of the football players during the training and match sessions such as the heart rate [20], oxygen level (O2) [21], steps [22], and the body energy level [23]. These parameters have an important effect on the training load for each player as mentioned in the listed studies.

The health indicators employed in this work significantly impact the performance of football players during exercises and consequently, the outcomes of matches. It is essential for coaches to monitor both internal and exterior training loads to effectively design appropriate load and recovery requirements and to evaluate the impact of training on fatigue and fitness changes within the same individuals [24]. The evaluation of heart rate (HR) has been suggested as a reliable method to gauge relative exercise intensity during cardiorespiratory activities, hence informing the intensity of training treatments designed to enhance aerobic fitness and avert over training [25]. The beats per minute (bpm) is the measurement unit for the heart rate. Blood oxygen level and anaerobic threshold are the primary metrics utilized to characterize aerobic performance capability and fundamental aerobic endurance. This metric is utilized by coaches and researchers to ascertain training intensity [26]. It is measured by percent (%). Furthermore, the count of steps per minute is an important element taken into account during the training regimen, as it shows a strong correlation with the running speed of the player [27]. The final health metric in this study is the body energy level of the player during exercise or actual competition. Players must demonstrate significant aerobic and anaerobic energy production capabilities to manage the distances traversed and facilitate recovery between intense efforts. Additionally, they should exhibit a strong capacity for repetitive high-intensity work and sprinting to mitigate muscle fatigue. Muscle fatigue progresses gradually at intensities that are below the threshold of aerobic energy

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systems, while it occurs more rapidly at higher intensities that activate anaerobic processes [28]. It is also measured by percent (%).

IV. PROPOSED SIMULATION SOFTWARE DESIGN

The Train Player is developed using python 3.10 and TKinter library to build the graphical user interface. It utilized the MQTT protocol for data exchange. With MQTT, nodes that are connected to a network are called "clients," and they communicate with a server known as the "broker" to exchange data. The broker is in charge of facilitating data transfers between clients. It is really tough to accomplish what the work needs in the footballer training scenario with other specialized network simulations which focus on the detailed node layers and the communication protocols and need extra plugins for integrating the MQTT. However, MQTT is flexible in sending different types of messages and compatible with multiple programming languages. It works in the application network layer and have undergone testing to determine their capabilities and the reliability of sending data [29].

The GUI simulate the real player in the football field. Each player has four types of health sensors (heart rate, oxygen level, steps count and body energy level). The players represent a wireless sensor node with integrated sensors. These metrics have an important role in the performance assessment during the training session; consequently, affect the performance level during the real match and the match result as mentioned in section 2. The general workflow of the developed program is illustrated in *Fig. 2*. The design is a Message Queuing Telemetry Transport (MQTT)-based for player physical status monitoring. The system consists of:

- Data acquisition module
- Communication module for message transmission
- Data saving module.

The proposed wearable sensors collect the data form each player and send it periodically to the mosquito local server. The broker should be started before running the program. *Fig. 3* shows the prompt used to start the connection with the mosquito broker with the players-data topic. The GUI of the Train Player has a field part with five running players and a local broker to receive the sent data from the players. It contains two buttons to start and end the simulation process. When the simulation starts, the players start to move on the field while the data is published to the broker every 10 seconds as seen in *Fig. 4*. The published data is presented in the lower part of the GUI to view the data and reset with each publish procedure. The duration of the simulation is 60 seconds; all the published data is saved in the mosquito server which installed as a local host. The data log will be saved into two files: data_log.csv and data_log.txt for further analysis. The files have six records for each player with different timestamps.

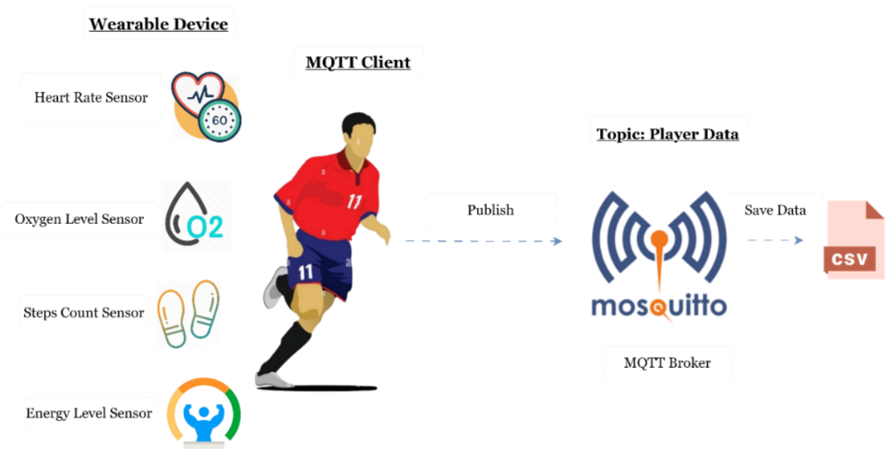

FIG. 2. TRAINPLAYER GENERAL DESIGN.

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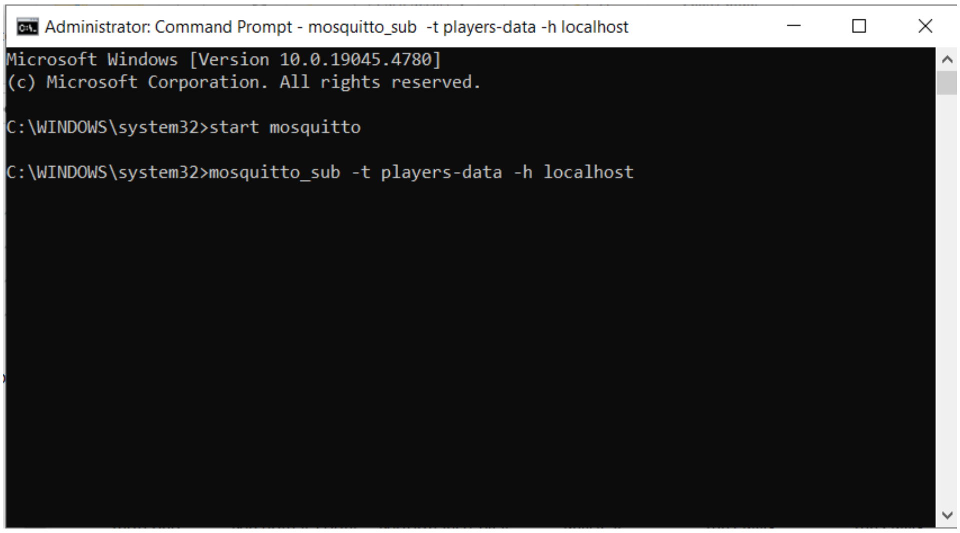

FIG. 3. START THE BROKER.

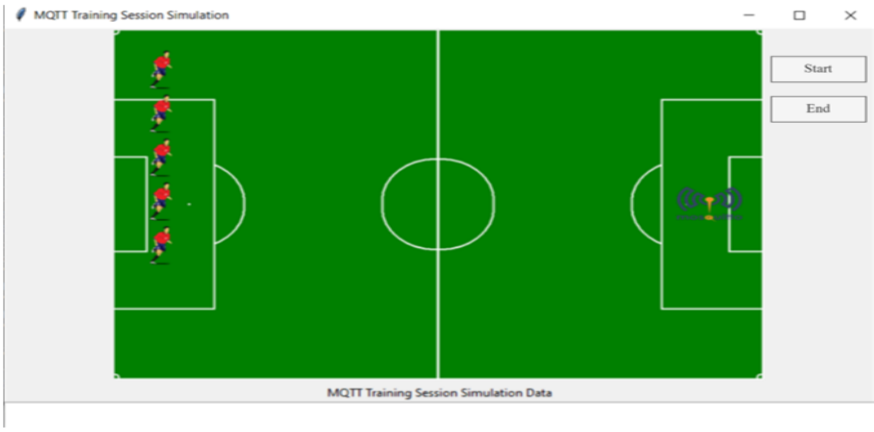

FIG. 4. TRAINPLAYER GUI.

V. EXPERIMENTS RESULTS AND DISCUSSION

Obtaining the results required a series of simulations, so the Train Player program was run to simulate the football player's health metrics during the training session. All the following analyses and discussions will depend on the obtained data to show the performance of the players during the training practice of each player. The experiments are done in the following environment: Corei7 hp laptop, Python 3.10 and Microsoft Windows 10 Pro operating system and 8 GB RAM. The work didn't test on other operating systems such as MAC or Linux. The results will present and explain the practical application of the software, in addition, the time delay will be presented and discussed. The time delay is computed as the difference between the data send timestamp from the players' nodes as (t_1) and the registered timestamp on the broker when receiving the data and view it in the terminal as (t_2). The time delay is computed using equation (1).

$$Time\ delay = t_2 - t_1 \tag{1}$$

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A. Practical Application Results

First of all, the broker should be started and connected to the targeted topic to be ready for data receiving as seen in *Fig. 3*. When running the TrainPlayer, the players start moving on the designed field with different health metrics to simulate the difference between players during the workload, and send the sensing data to the broker every 10 seconds. The sent data appeared in the GUI and the broker simultaneously as illustrated in *Fig. 5a* and *Fig. 5b*. In addition, it logged to the log's files with the time stamp appeared in the last column. *Fig. 6a* and *Fig. 6b* presented the files snippet.

In the experiment, every client replicates numerous players submitting data to the broker by publishing his data to the Broker's Players-Data topic. The outcomes demonstrate the low latency of the MQTT protocol in scenarios involving multiple players. Furthermore, MQTT can deliver dependable and timely messaging services to wearable devices with low data volumes and constrained bandwidth, suggesting that its use in the sports industry is feasible.

From the saved data file, further analysis can be performed to assess the performance of the player at each training workload. The initial analysis of *Fig. 7a, 7b, 7c, 7d* and *7e*, it is clear that the heart rate and the steps are positively correlated and consider as normal indicator if the oxygen and the body energy stay within the normal ranges. If the generated data is passed through more specialized analysis, the coaches can develop the training procedure for more effective levels within a short time. Accordingly, the playing level will produce more winning scores which is the main goal of the football teams.

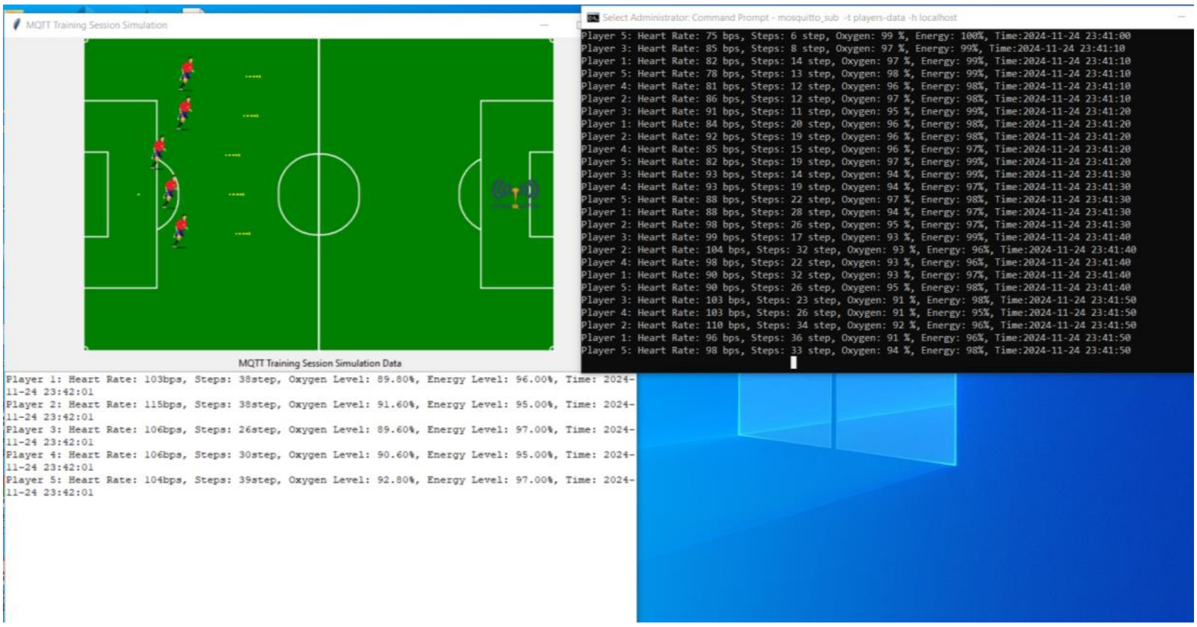

FIG. 5A. RUN SNIPPET1.

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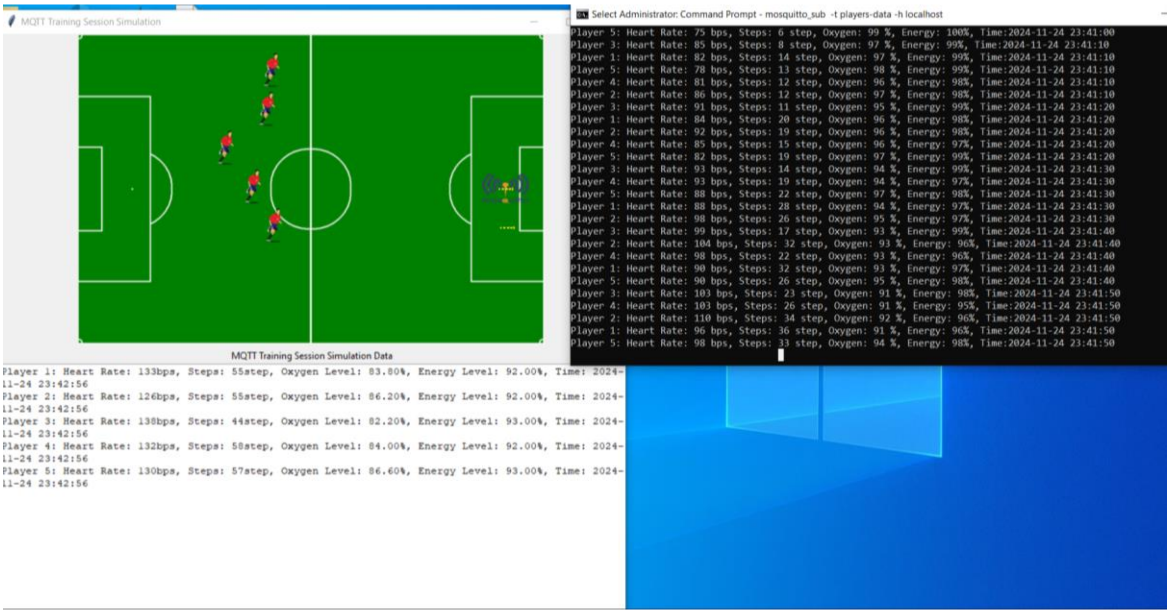
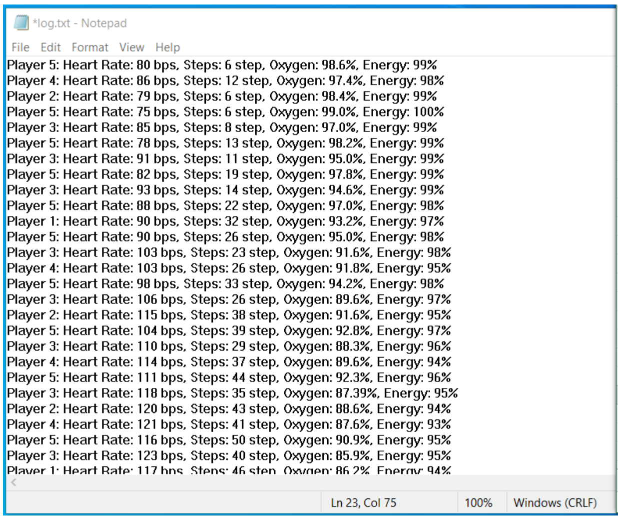
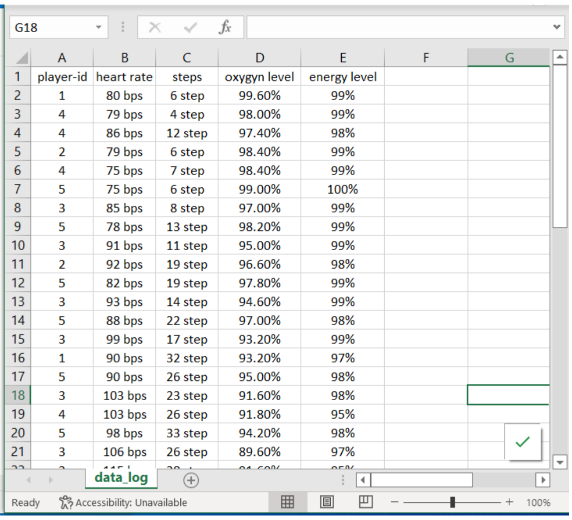


FIG. 5B. RUN SNIPPET2.





	A	B	C	D	E	F	G
1	player-id	heart rate	steps	oxygyn level	energy level		
2	1	80 bps	6 step	99.60%	99%		
3	4	79 bps	4 step	98.00%	99%		
4	4	86 bps	12 step	97.40%	98%		
5	2	79 bps	6 step	98.40%	99%		
6	4	75 bps	7 step	98.40%	99%		
7	5	75 bps	6 step	99.00%	100%		
8	3	85 bps	8 step	97.00%	99%		
9	5	78 bps	13 step	98.20%	99%		
10	3	91 bps	11 step	95.00%	99%		
11	2	92 bps	19 step	96.60%	98%		
12	5	82 bps	19 step	97.80%	99%		
13	3	93 bps	14 step	94.60%	99%		
14	5	88 bps	22 step	97.00%	98%		
15	3	99 bps	17 step	93.20%	99%		
16	1	90 bps	32 step	93.20%	97%		
17	5	90 bps	26 step	95.00%	98%		
18	3	103 bps	23 step	91.60%	98%		
19	4	103 bps	26 step	91.80%	95%		
20	5	98 bps	33 step	94.20%	98%		
21	3	106 bps	26 step	89.60%	97%		

FIG. 6A. LOG.TXT FILE.

FIG. 6B. LOG.CSV FILE.

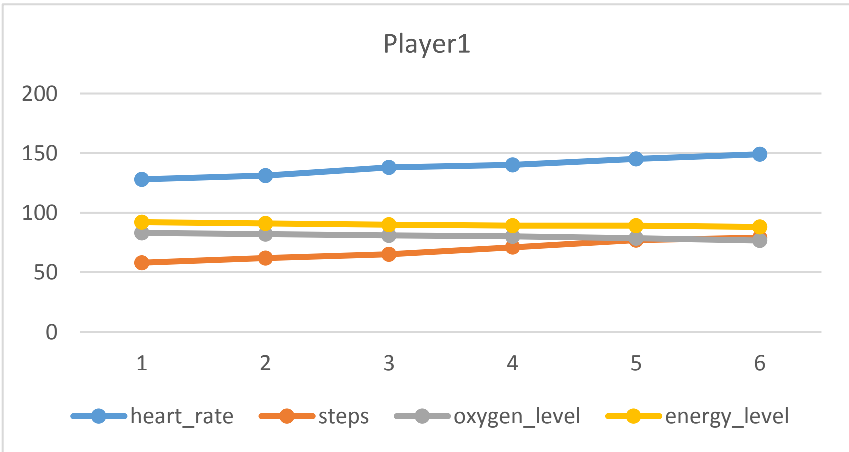


FIG. 7A.

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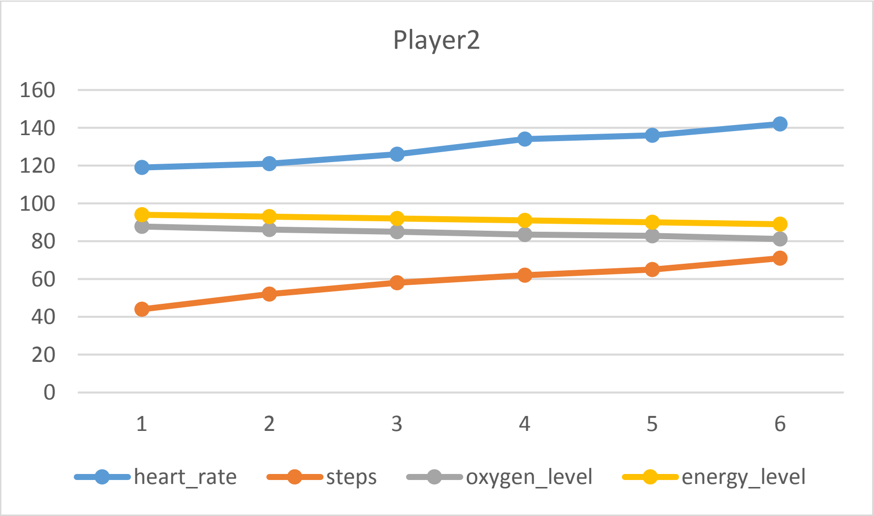

FIG. 7B.

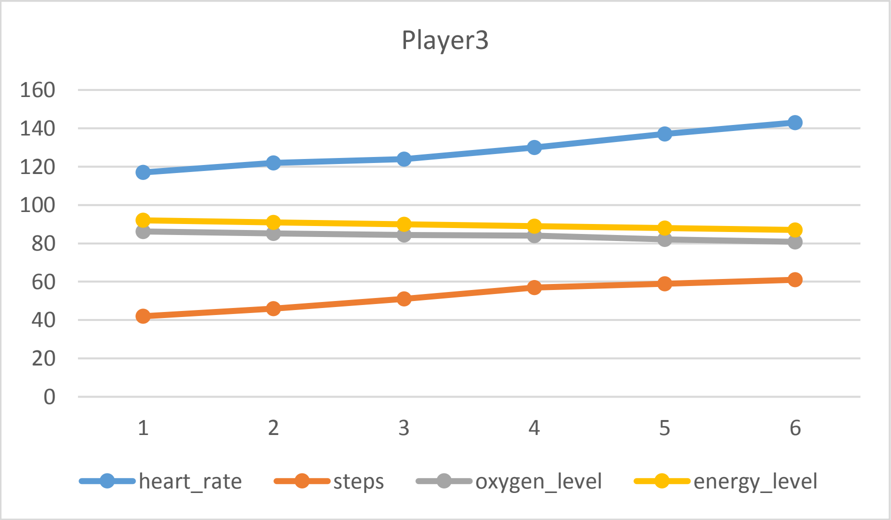

FIG. 7C.

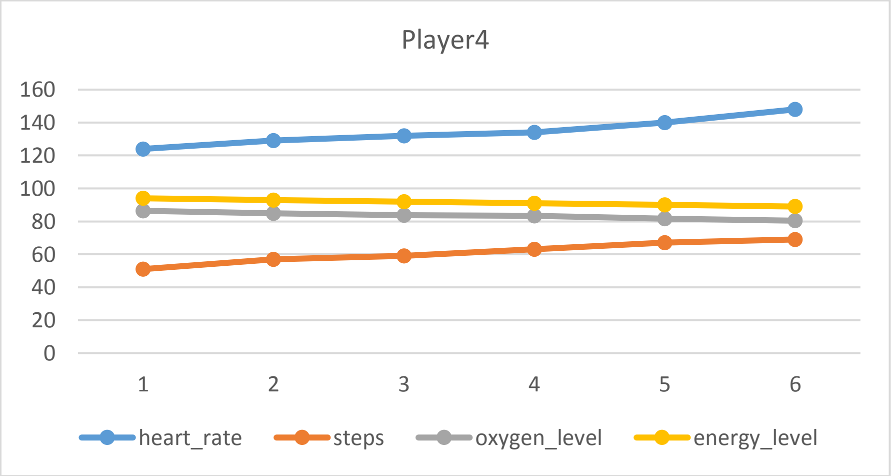

FIG. 7D.

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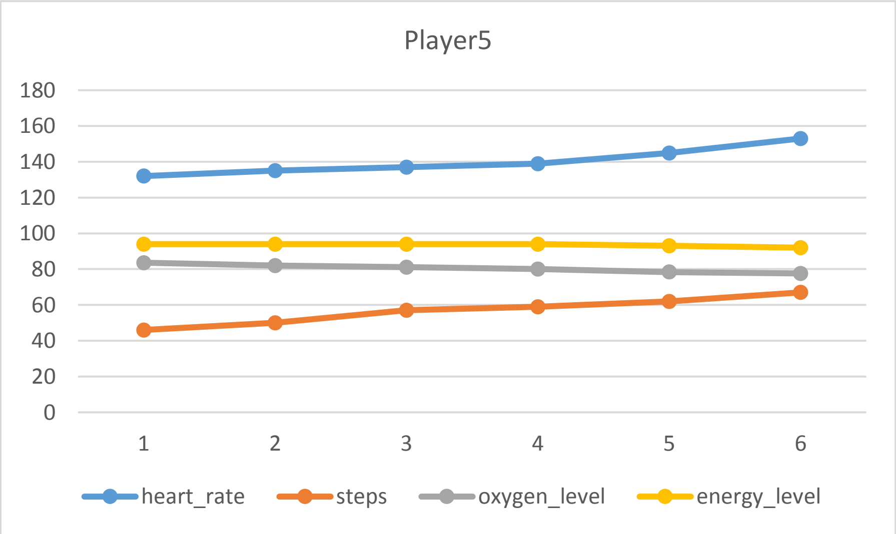

FIG. 7E.

B. Time Delay Results

During the practical experiments, the time to send the packets from the player's nodes to the MQTT mosquitto server is presented in Table II. The displayed time in the table is the local time in the operating system of the laptop. The experiment period long time was 60 seconds; the sensor data is sent periodically every 10 second which represent a time slot. As noticed from the presented results, there is a time delay equal to 1 second between sending the data from the players' nodes to the MQTT local server. This depended on the processing speed of the used computer. This is acceptable value and it could be decreased if more powerful CPU and the RAM is used. The time delay value should be remained within minimum values in the internet of things environments. In case of using a cloud server, this time may increase depending on various factors such as network latency and bandwidth, protocol overhead and the server processing capacity to handle incoming data. All these factors should be considered when developing real IoT system. In addition, all the packets sent from the nodes were received successfully in the server side, this means there is no drop was happened and the reliability is confirmed.

TABLE II. SEND AND RECEIVE TIME

Session No#	Player id	Send Time	Received Time
Time slot 1	P1	11:46:38	11:46:38
	P2	11:46:38	11:46:38
	P3	11:46:38	11:46:38
	P4	11:46:38	11:46:38
	P5	11:46:38	11:46:38
Time slot 2	P1	11:46:48	11:46:49
	P2	11:46:48	11:46:49
	P3	11:46:48	11:46:49
	P4	11:46:48	11:46:49
	P5	11:46:48	11:46:49
Time slot 3	P1	11:46:58	11:46:59
	P2	11:46:58	11:46:59
	P3	11:46:58	11:46:59
	P4	11:46:58	11:46:59
	P5	11:46:58	11:46:59

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Time slot 4	P1	11:47:08	11:47:09
	P2	11:47:08	11:47:09
	P3	11:47:08	11:47:09
	P4	11:47:08	11:47:09
	P5	11:47:08	11:47:09
Time slot 5	P1	11:47:18	11:47:19
	P2	11:47:18	11:47:19
	P3	11:47:18	11:47:19
	P4	11:47:18	11:47:19
	P5	11:47:18	11:47:19
Time slot 6	P1	11:47:28	11:47:29
	P2	11:47:28	11:47:29
	P3	11:47:28	11:47:29
	P4	11:47:28	11:47:29
	P5	11:47:28	11:47:29

VI. CONCLUSIONS

Simulation software is the pre step before hardware implementation. It gives a real scenario data for the real time world. In this work, the Train Player software is developed to simulate the most important health metrics that affect directly on the football player fitness during the practices. As a plan for future work is to implement this work in a real sensor network as a bracelet with the ability to send the collected data by the local base station to a cloud server to be analyzed remotely and view the results in a real web interface. In addition, the obtained results file will be considered for further analysis using statistical or machine learning algorithms to capture the common patterns in the player's performance that can be improved by selection the appropriate workload by the trainer. The most important patterns in the performance assessment are the acceleration and deceleration, running speed, distance covered and others. This software can be expanded to include more performance parameters in the training and the match sessions to be a comprehensive simulation tool specialized in the use of the IoT technology in the sport industry. However, some limitations of this work, is the environmental noise and attenuation are not considered in the current version.

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