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Monitoring and Analysing the Performance of Runners using the Internet of Things

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Running is a common and easily accessible physical activity that greatly enhances mental and cardiovascular health. The development of technology has completely changed the way we think about fitness. However, the absence of a sophisticated and intelligent running tracking system poses several problems. Among the problems running enthusiasts face is recording the data and analysing the runner for coaches to monitor their health in field paces, heart rate, and distances using wearable devices. In the absence of monitoring, the runner is incautious about their condition while running to avoid injury. The objectives are: to design the implementation of wearable devices equipped with sensors to record comprehensive data during a runner's activity; to develop a system for coaches to monitor and track the health and performance of runners in real-time; and to test the effectiveness of the sensor monitoring system in promoting runner awareness and preventing injuries during running. The methodology is to create a wearable device sensor using IoT components that can easily attach and detect the runner's health accurately. In this project we can expect that the system should seamlessly function once installed on the runners, the data will be forwarded to the server attached to the laptop where the coaches and admin can view the runner's health status. Also, the device can trace and record the data without causing any problems. Hence, the objective of the result is to study a better-running tracking system by analysing its limitations, especially concerning accurate data storage, real-time performance analysis, and personalized insights. The embedded device can record the health status and able to be monitored by the coach. The combination of embedded technology and monitoring systems will effectively prevent injuries among runners. The technologies/tools used are MKR1010, Arduino IDE, Laravel, Firebase, PHP, and Processing IDE.

Keywords: IoT, Wearable Device, Sports, Running, Tracking.

مراقبة وتحليل أداء العدائين باستخدام إنترنت الأشياء

الخلاصة

يعد الجري نشاطًا بدنيًا شائعًا ويمكن الوصول إليه بسهولة ويعزز الصحة العقلية والقلب والأوعية الدموية بشكل كبير. لقد أدى تطور التكنولوجيا إلى تغيير الطريقة التي نفكر بها في اللياقة البدنية تمامًا. ومع ذلك، فإن غياب نظام تتبع الجري المتطور والذكي يطرح العديد من المشاكل. ومن بين المشاكل التي يواجهها عشاق الجري تسجيل البيانات وتحليل العداء للمدربين لمراقبة صحتهم في خطواتهم الميدانية ومعدل ضربات القلب والمسافات باستخدام الأجهزة القابلة للارتداء. في غياب المراقبة، لا يهتم العداء بحالته أثناء الجري لتجنب الإصابة. تتمثل الأهداف في: تصميم وتنفيذ أجهزة يمكن ارتداؤها مزودة بأجهزة استشعار لتسجيل البيانات الشاملة أثناء نشاط العداء، وتطوير نظام للمدربين لمراقبة وتتبع صحة وأداء العدائين في الوقت الفعلي، واختبار فعالية المستشعر. نظام المراقبة في تعزيز وعي العداء ومنع الإصابات أثناء الجري. تتمثل المنهجية في إنشاء جهاز استشعار يمكن ارتداؤه باستخدام مكونات إنترنت الأشياء التي يمكنها بسهولة ربط صحة العداء واكتشافها بدقة. في هذا المشروع، يمكننا أن نتوقع أن يعمل النظام بسلاسة بمجرد ارتداء العدائين له، وسيتم إرسال البيانات إلى الخادم المتصل بالكمبيوتر المحمول حيث يمكن للمدربين والمسؤول عرض الحالة الصحية للعدائين. كما يمكن للجهاز تتبع وتسجيل البيانات دون التسبب في أي مشاكل. ومن ثم، فإن الهدف من النتيجة هو دراسة نظام تتبع يعمل بشكل أفضل من خلال تحليل البيانات المستقبلة، خاصة فيما يتعلق بتخزين البيانات الدقيقة، وتحليل الأداء في الوقت الحقيقي، والرؤى الشخصية. يمكن للجهاز ايضاً تسجيل الحالة الصحية للاعب ويمكن للمدرب مراقبتها. إن الجمع بين التكنولوجيا المدمجة وأنظمة المراقبة سيمنع بشكل فعال وقوع إصابات بين العدائين. التقنيات/الأدوات المستخدمة هي MKR1010و Arduino IDEو Laravelو Firebaseو PHPو Processing IDE.

1. Introduction

There is no doubt that sports activities can increase a person's physical and mental endurance in terms of cardiovascular, metabolism and muscle strength. This is further reinforced by the statement that conventional exercise approaches, such as high-intensity interval training, endurance running, and strength training, are widely acknowledged for their efficacy in improving cardiovascular, metabolic, and musculoskeletal fitness, respectively. Furthermore, participating in diverse exercise regimens can efficiently activate all three fundamental fitness domains, leading to holistic fitness and health benefits [1]. Hence, as technology advances and grows more advanced with each passing year, it has acquired a significant function in sporting activities and is increasingly utilised by various segments of society, including ordinary citizens, athletes, and professional trainers. Technology has allowed greater user-centred design solutions for various industries. There is a growing trend of increasingly quantifying achievements being used by consumers daily, whether it is fitness, health, or work related. Wearables that possess sensors to monitor how the body is manoeuvring gives the user greater understanding of themselves [2].

There are plenty of sensors that have been used for athletics performance, usually, several sensors are used to acquire an acceptable compression system analysis. All these sensors can be classified into three categories: motion sensor, physiological sensor and contextual sensors. Motion capture technology is widely used in every kind of sports and a little interval of time can be highly significant because it differentiates an athlete’s performance from others. As a result, kinematic analysis using wearable sensors provides real-time feedback and coaches can estimate when the players can recover from injury.

Most technologies employed in sports utilise sensors to ascertain the physiological condition

of an individual or athlete. Advances in sensors allow deeper measuring capability. Users learn more about themselves, thus changes to their lifestyle can be made under their control. Applying sensors to equipment is another way to show progress in sensor technology [2]. The advancement of technology has progressed significantly with the emergence of wearable devices that enable individuals to use them during physical activities. Wearables can be defined as a small electronic and mobile devices or computers with wireless communications capability that are incorporated into gadgets, accessories, or clothes, which can be worn on the human body, or even invasive versions such as micro-chips or smart tattoos [3]. Recreational users typically favour compact and adaptable gadgets for use during physical activities, such as those that may be attached, inserted into footwear, worn as wristbands, or used as earbuds [4]. Several studies have been undertaken to assess the health status of athletes using a range of wearable technologies, including shoes, shirts, cameras, straps, and smart sports bras. This study specifically examines the use and quantification of wearable gadgets in the context of running sports. Our primary focus is on developing wearable devices that possess the capability to precisely measure temperature, pace, heart rate, and injuries. These gadgets are designed to be user-friendly and simply utilised by runners.

1.1 Problem Statement

Sports have emerged as a popular and all-encompassing pastime for individuals seeking to manage their daily schedules well. Studying the efficiency of sports activities is crucial to ensure a healthy body and minimize injuries by understanding the body's actual condition during physical exertion. The reliance on technology in sports greatly aids in the detection of internal bodily conditions during athletic activities, as human perception is inherently limited without the use of technological tools. Therefore, to record data and analyse runners for coaches to monitor their health [5] in the field pace, heart rate, body temperature and distance by implementing a wearable device is used to collect data for the purpose of collecting and analysing data about their status such as athlete health, allowing coaches to monitor their wellbeing. According to Seshadri et al., [6] lacking awareness of their physical condition leads the athlete to disregard the application of a sensor monitoring system designed to prevent injuries. Internal injuries may transpire during athletic activities when thorough and efficient surveillance is lacking [7], which may result in detrimental and enduring consequences for the athletes.

1.2 Objectives

The objectives of this study are to design the implement of wearable devices equipped with sensors to record comprehensive data during a runner's activity; to develop a system for coaches to monitor and track the health and performance of runners in real-time; and to test the effectiveness of the sensor monitoring system in promoting runner awareness and preventing injuries during running.

1.3 Limitation of works

Real-time accuracy of data storage: There is a chance that the wearable devices might not give an accurate depiction of the runner's health, missing some physiological or physical details that are important for avoiding injuries. While the system allows the use of wearable technology, challenges may arise when the effectiveness of the sensor monitoring system may

be influenced by technological limitations, including device accuracy and reliability.

1.6 Literature Review

Sports activities are now a trend in increasing the use of technology to measure the health level of individuals, athletes and coaches especially in the use of wearable technology during sport activities. Most of the use of wearable technology now capable of tracking heart rate, pace, distance, sleep patterns and even detecting injuries has also been made by previous studies [8]. Thus, wearables are intended to help consumers achieve a state of self-connection by using sensors and software that facilitate data exchange, communication, and access to information in real-time. For this reason, wearable devices are a large part of the content of the Internet of Things (IoT) [9]. Until now, there has been a lot of production of wearable technology that has been released by companies across the country to accommodate the growing demand as it appeals to individuals of all age groups, ranging from youngsters to adults [10]. The most importance use of wearable technologies are basically to monitor the health issue of users apart from use it as a sport training. Therefore, the use of wearable technology in detecting injuries has been used by athletes and is even important for paralympic athletes. This statement has been supported by [11] technology has been used to improve and support the athlete's training and development in both elite and amateur sports for non-disabled and people with disabilities.

In recent year various wearable technologies have been created to measure the health level of athletes such as strap, smartwatch, smart sport bra, smart shoes, smart belt, wristwatch and the accuracy results are also different (based on table 1). Most users are more likely to use smartwatches or wristwatches that are easy to use on the body and the result of determination in measuring the user's health level is more accurate. In this realm, a solution based on smartwatch/ fitness tracker can be proven promising considering its unobtrusive nature, pervasiveness, and convenient wearability. They are commercially available off the shelves at a modest price and have recently gained a lot of attention from the health and fitness communities. According to a recent study [12], International Data Corporation (IDC) reported an estimate of 69.3 million smartwatches to ship in 2019, and a total of 109.2 million units to reach worldwide markets by 2023 which shows that wearable based solution is the future of fitness and healthcare. Further, a study in [13] addresses the prevalence of wrist- worn wearables in the fitness industry, utilized by amateurs and professionals. Moreover, the study underpins the necessity to develop precise health and fitness applications by leveraging sensors embedded in the wearables.

1.7 Related Works

Table 1: comparison method by using variety technology devices from previous research

Method	Size	Sensor	Accuracy	Availability For Consumer	Utilization	Wearable
Eitzen (2021) [14] Smart Watches	Not Specified	Accelerometers	Based On Type of Sports	Yes	Force Plates, Treadmill, Camera,	Yes

					GPS Enabled Watch	
Romano (2023) [15] Strap	Small	Accelerometer And Gyroscope	Accurate For HR, Sleep, Strain	Yes	Softball, Women's Lacrosse, Baseball	Yes
Navalta (2020) [16] Smart Sport Bra	Not Specify	Fabric Heart Rate Sensors, Flexible Plastic Sensors	Weak Accuracy For HR	Yes	Walking, Running	Yes
Jennifer (2019) [4] Earbud	Small To Large For Earwings, Eargels, And Foamtips,	Optical Heart Rate Monitor	Accurate For HR	Yes	Treadmill, Running, HIT	Yes
A. Soltani (2020) [17] Wrist	Small	Accelerometer And Barometer Sensors	Accurate For Running	No	Walking and Running	Yes
Bernhart (2022) [18] Chest Strap	Not Specify	Smart Textile Sensor, Accelerometer	Accurate For Breathing (HR)	No	Walking, Treadmill, and Running	Yes
Drashti Gokalgandhi (2020) [19] Shoes	Medium	Accelerometers, Pressure Sensor, Ultrasonic Sensor, Temperature Sensor, Gyroscopic Sensor, Piezo-Electric Pedometer	Accurate For Walking And Running	Yes	Long Distance Running, and Walking	Yes
Bernardina GRD (2019) [20] Camera	4 Cameras	Optoelectronic Cameras	Low Accuracy	No	Walking and Running	No
Tarekegn (2023) [21] Smart Belt	Medium	MKR Wi-Fi 1010, IMU (BOSCH BMI088)	High Accuracy	No	Walking, Jogging, Walking Upstairs, Walking Downstairs, Sitting, And Standing.	Yes

The work developed by Ziyad et. al., [22] running a system-related project for tracking 100-meter sprint performance. An athlete's performance is monitored by a system called a Performance Monitoring System (PMS). Athletes can track their performance using the PMS in ways including total steps, total time, time utilized for each step, and distance used for each step. Researchers use shoes equipped with hardware sensors that contain a GPS module to measure the distance used for each step. The data from the FSR sensor and GPS module was sent to an XBEE for real-time display on a laptop. As a result of this study, the accuracy of step detection yielded results that showed 90% of steps were detected at moderate speeds and 93% at high speeds. At low speed and high speed, the time detection accuracy for each step was 96.77% and 92.22%, respectively.

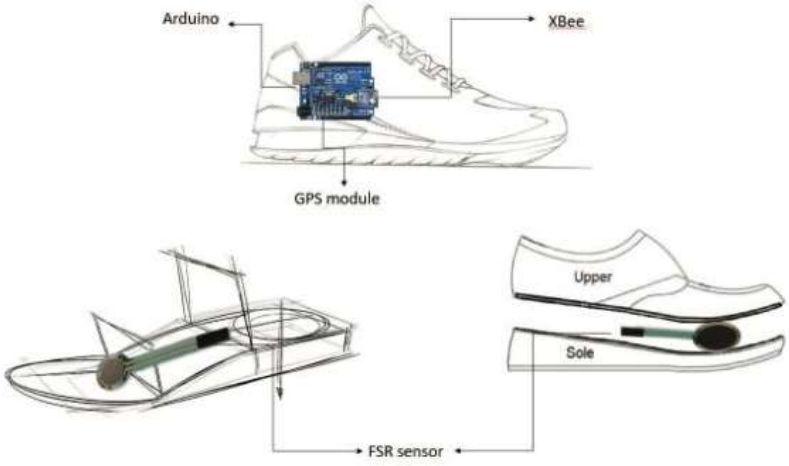

Figure 1. Sensor Placement in Shoes [14].

The work from article "Development of a platform for sensor systems support in sport" written by Matevž Hribernik et. al., [23], it is related to the potential of sensor systems to improve athletic performance and the importance of effective data management in achieving this goal. It uses the API (Application Programming Interface) to enable different types of users to access and interact with the data stored in the platform for sensor systems support in sport [23]. Sensor systems contribute to the improvement of athletic performance in sports by providing accurate and objective data on various physical parameters, such as movement, speed, and force. This data can be used to identify areas for improvement, track progress, and optimize training programs. For example, wearable sensors can be used to monitor an athlete's movements during training or competition, providing real-time feedback on technique and form. This can help athletes adjust their movements to improve performance and reduce the risk of injury. In addition, sensor systems can be used to track an athlete's progress over time, allowing coaches and trainers to adjust training programs to optimize performance. This can help athletes reach their full potential and achieve their goals.

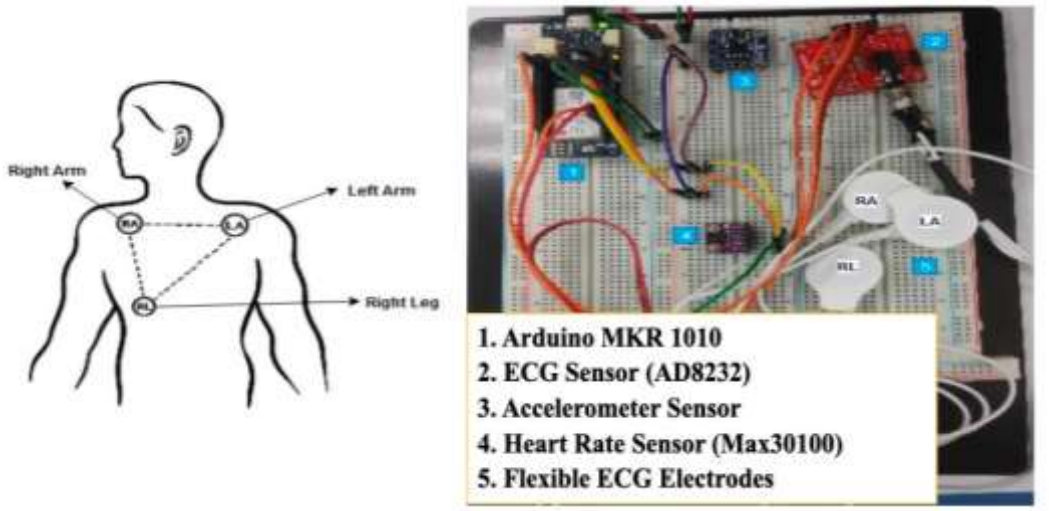

Figure 2. Smart Chest Strap [16].

Previous work by Prosenjit Kumar Ghosh and Prabha Sundaravdivel [24] made a study on smart chest strap for athlete health monitoring system using AD8232 ECG sensor, MMA8451 Accelerometer sensor and MAX30100 Heart Rate Sensor used for athlete health monitoring. The data obtained from these sensors is used to create a thermal profile for the athlete. The hardware part of this project consists of an Arduino MKR 1010 unit based on a SAMD21 Cortex-MO low power consumption microcontroller unit including an integrated sensor. In this study, a sensor will be placed on the chest to detect the heart rate. Therefore, the chest band will record the mobility of each athlete and provide insightful information about the athlete's current state of health. Figures? shows a demonstration of the chest strap and hardware components.

With the advent of IoT, the integration of wearable technology into sports and fitness has changed the way athletes train, compete and monitor their overall health. Wearables are designed to assist consumers in establishing a state of self-connection through the utilization of sensors and software that enable real-time data exchange, communication, and access to information. Therefore, wearable gadgets constitute a significant portion of the material within the Internet of Things (IoT) [25]. Employing the Internet of Things (IoT) technique in Smart Wrist is very important in developing a wearable device that allows the device to track the user for data collection for future research purposes.

Physiological and kinanthropometric such as weight, height, blood pressure etc. measurements are crucial in the field of sport and exercise science since they enable the monitoring, evaluation, and development of training programs [26]. By measuring physiological characteristic able to make decision making for purpose study. For Smart Wrist, we developed technology that allows the component to detect the level of health and performance of runners by detecting several physiological and kinanthropometric components such as weight, height, heart rate, body temperature and distance for coach able to monitor in future.

2. Methodology

This study uses the systematic literature review method to identify and review the extant research on wearable technology. This study was undertaken by comparing the findings of past studies to assess the available wearable technology in the market. This prior study has been utilized to assess the efficacy of wearable technology in accurately detecting the determination of the health condition of athletes or those using such devices. Previous studies extensively utilized accelerometer and gyroscope sensors to monitor heart rate, blood pressure, and body temperature. Additionally, GPS was employed to assess the user's pace, distances, and steps.

To investigate the health of the athlete, a few physiological parameters can be measured to get a better understanding of the health status and create a stress profile. We have used a MKR 1010 which offers both Bluetooth and WiFi connectivity to a smartphone or another external device for the remote monitoring of the patients. The system also comes equipped with temperature using LM35 and specific heart rate sensors using HW-827 Sensor, and it can be powered by a rechargeable power bank battery. In this study, we implemented the prototype on an Arduino MKR 1010 (Arduino, Italy) owing to its 12-bit resolution, large flash memory, in-built Bluetooth feature, multiple PWM-enabled pins (13) and the fact that it is about ten years newer than other models, and to the best of our knowledge, has not been evaluated for ECG signal processing [27].

To get a person's whereabouts, GPS can help detect and track the distance between an area in the form of latitude and longitude. The GPS is a satellite-based navigation system that sends data from satellites [28-43]. A GPS system consists of group of satellites and well-developed tools as receiver. GPS receiver is the main device in this system. This component receives the coordinates from the satellite for every second, with date and time. The use of GPS receiver is processed by the microcontroller to extract its latitude and longitude values. The microcontroller processes this data and sends the information to the mobile phone. It gives the precise information about location in a real time. In this study, we use GPS using Google Maps to track the distances of athlete during running while the system will measure the paces of each kilometre in a real time. This study utilises a database to store user data, including information on administrators, coaches, and runners. The database also stores data collected during running training sessions, which is then analysed by the coach to assess the runner's success in sports. Real-time data storage is crucial for ensuring the accuracy and usability of the received data during the assessment. The data storage software being utilised is Firebase version 9. In order to display runner data, we have employed web hosting as a method whereby a web hosting provider stores and manages website files and software on a server, enabling runners' websites to be available on the internet.

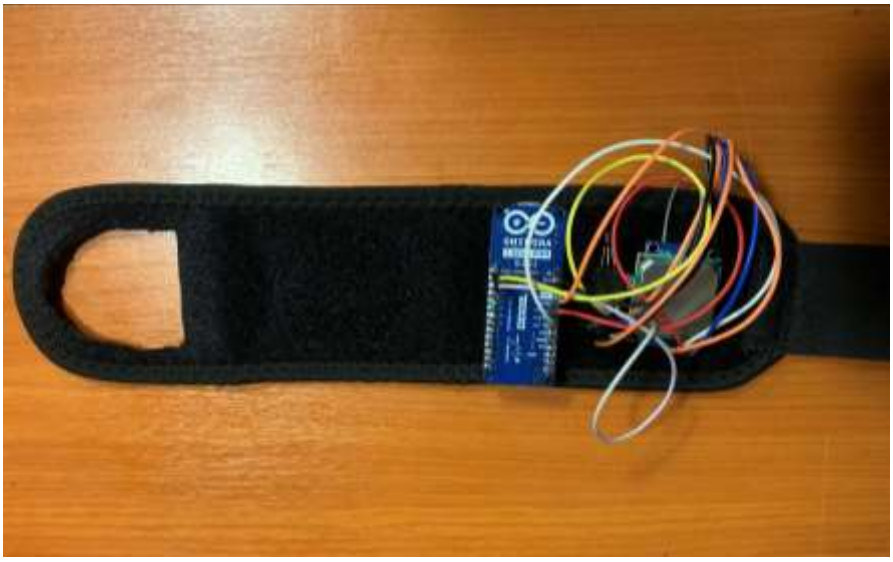

Figure 3. the design installation of sensors.

Based on figure 3, this implements the component and sensors such MKR1010, LM35, HW-827, GPS Module and power bank on a device. All the component and sensors are connected to Arduino MKR1010

Figure 4. Smart Wrist Proof of Concept.

Based on figure 4, the demonstration of designed device smart wrist on outdoor.

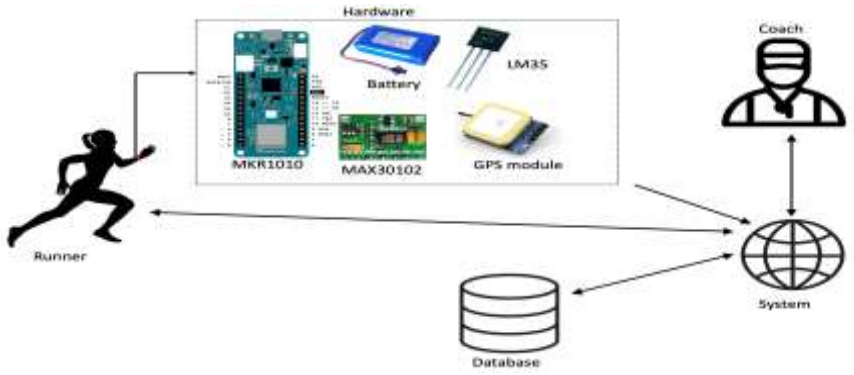

Figure 5. Wearable device sensor monitoring system framework

In this research, we propose an IoT-based framework for measuring both physical and GPS of runners. The framework shows a brief overview of the structure of the set of tools, software and hardware that would be used in the project that allows developers to create applications more reliability and efficiently. This framework would help in recording distances, Heart rate, body temperature and performance of the user and created a user profile accordingly. The thematic overview of the proposed wearable device system was given in figure 5. The proposed framework would use a smart wrist that runners able to wear on hand along with a system to help in creating a physiological profile for runners using which the trainers, administrator and coaching staff could monitored the runner's health. From these devices, all information was collected and stored in the cloud database continuously for future inspections. The coach or trainer would monitor the runner's health condition via system that connects to the laptop once the data already collected within internet connectivity. The proposed framework could be easily integrated as a lightweight health monitoring framework for performance analysis in runners.

3. Result

Figure 6. Real Time Running Data in Firebase

Figure 7. Result Display in System

Result represents based on the data obtained through sensors, the received data will be stored in a database using Firebase as shown in Figure 6. The data obtained is in real-time where the current movements during running are recorded by the sensors. The data stored in Firebase will then be retrieved in the developed system, displaying body temperature, heart rate, location, date, time, and status, which will be analysed by the coach as shown in Figure.

4. Conclusion

This project was carried out to help athletes evaluated their performance during training with the help of a coach that allows athletes to anticipate their conditions during the run. All the runner's information would be displayed in a system that allows the coach to make decisions based on performance during training and make improvements in the future. The constraints that occur during the implementation of this project were in producing a wearable device using IoT components that could be worn during running training by athletes. The alternative was to find some relevant information on the internet about the production of wearable devices. In summary, IoT wearable device focuses on running athletes that allows them to know their performance during running with the help of a trainer who would monitor and evaluated the athlete's running results. Therefore, it was hoped that this project could help solve the problem of athletes who were difficult in determining their performance during training.

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