



Wearable Coaching System

Nur Alia Athirah Hj Mohtadzar^{1*}, Dyg Norkhairunnisa Abang Zaidel¹, Abdul Rahman Kram¹, Kasumawati Lias¹, Shahrol Mohamaddan¹, Mohamad Shaiful Abdul Karim², Yon Syafni Samat³, Shigeru Takayama⁴

¹Faculty of Engineering

Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, 94300, MALAYSIA

²Faculty of Electrical and Electronics Engineering

Universiti Malaysia Pahang, Pekan, Pahang, 26600, MALAYSIA

³Faculty of Built Environment

Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, 94300, MALAYSIA

⁴Faculty of Science and Engineering

Ritsumeikan University, Kusatsu, Shiga 525-8577, JAPAN

*Corresponding Author

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Abstract: Wearable Coaching System is a multi-sensor device for real-time training coaching. The system comprises of six modules which are shoulder, waist, a pair of wrist and a pair of ankle modules. It is compact, light, comfortable to wear and is suitable for any size of user. It system has five main embedded sensors: heart rate, three-axis acceleration, gyro, temperature and blood oxygen saturation (SpO₂) sensor. It operates in streaming mode for real-time data processing using two telecommunication tools: ZigBee and Bluetooth and low energy interface for recording mode is using an internal flash memory. In this paper, a wearable coaching system is designed to help athlete or trainer to perform proper and efficient exercise suitable to one's body needs. It measures the parameter of the body, analyze and provide feedback in a form of an advice. In order to improve the system, arm gesture mode performed by the wrist modules of the system is applied. This mode is to enable user to manage their exercising level to a more appropriate pace, suitable with their individual body by reproducing the feedback. In a supervised coaching training, percentage of heart rate threshold target is increasing, hence, producing a greater performance of training. It is proven in this paper, that wearable coaching system performs an accurate measurement in enhancing sports and coaching training, adding value to novel lifestyle exercising and health monitoring.

Keywords: Coaching, monitoring, exercise, heart rate, wearable, sensor, ZigBee, bluetooth

1. Introduction

A wearable coaching system is a combination of wireless sensor interacting with each other and actuators in order to coach an athlete training performances. [1] Lack or no monitoring of moderate activity or exercises such as walking, running or jogging could potentially pose serious threats to the human body. For instance, the incorrect body postures or excessive running could strain the body and lead to health problems such as back pain, slipped disks or knee pain. [4] One of the ways to minimize the health risks, is by designing a wearable system to monitor the body parameters

*Corresponding author: mnaathirah@unimas.my

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involved during the exercising. This should be beneficial towards a better health conditioning as they cover real-time medical information gathering obtained from different sensors with secure data communication and low power consumption. [7]

System to supervise moderate exercise intensity is necessary. Appending regular exercise into daily schedule may seem difficult at first, but with practical and precise supervising and coaching devices such as the wearable modules from the system, physical exercises and training become more accessible [5]. This system helps to coach and analyze the body parameters and subsequently provide quick input to the user during the exercise in real time [6]. It provides the freedom to reach the maximum necessary exercise goals through minor amounts of activities to the body. Fig. 1 and Fig. 2 show the pattern of heart rate during unsupervised and supervised exercise using wearable coaching system.

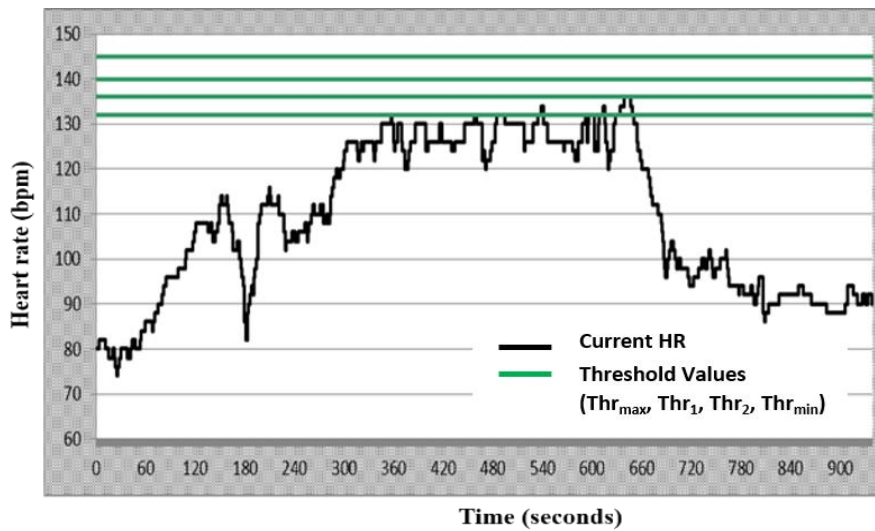


Fig. 1 - Heart Rate During Unsupervised Exercise

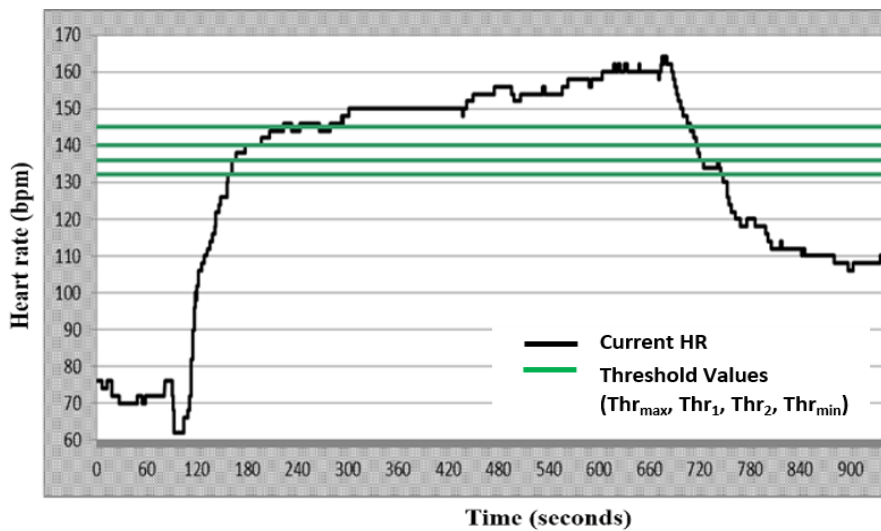


Fig. 2 - Heart Rate During Supervised Exercise

The threshold area is the most appropriate area of heart rate at exercise level. This area is illustrated in green lines. It is determined by using Karvonan formula, a mathematical formula to calculate targeted heart rate area. The heart rate during unsupervised exercises is expected to exfiltrate the threshold area, while the heart rate infiltrate during supervised exercises. Arm gesture mode from wrist module provides additional function to the coaching system. In this function, wrist modules incorporate with shoulder module, will trigger feedback function in sound module to reproduce new advice for the user. With this, the user will be able to control the system in ways that benefit themselves.

2. Development of Wearable Coaching System

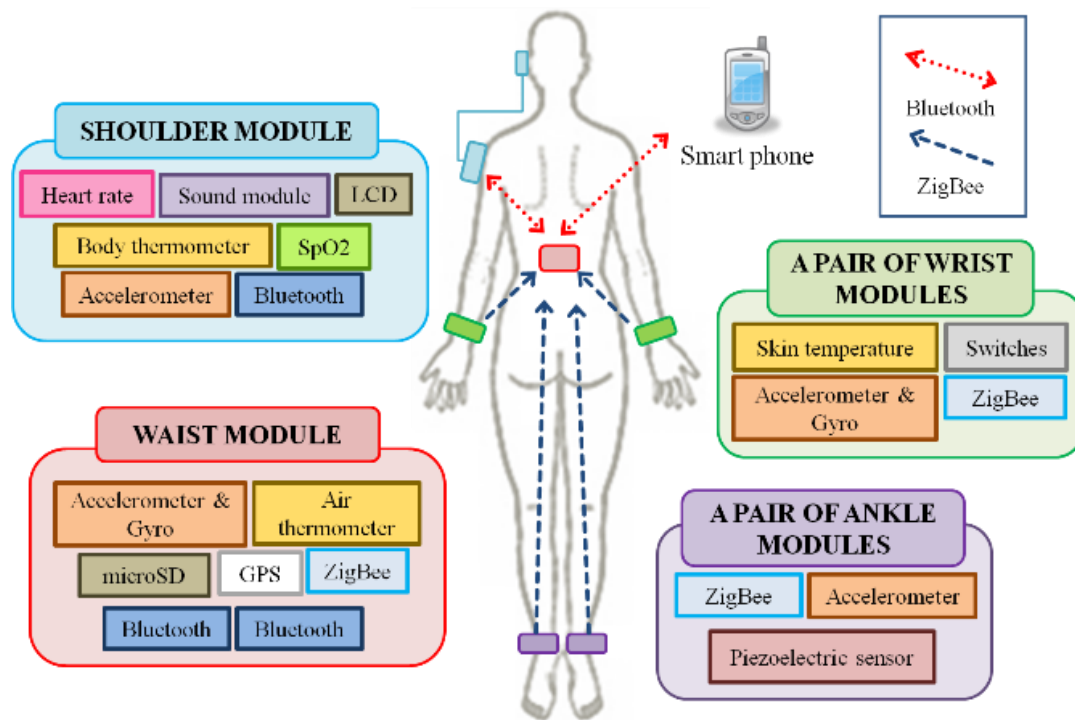


Fig. 3 - Design of Wearable Coaching System

The construction of wearable coaching system is shown in Fig. 3. The system comprises of a shoulder, a waist, a pair of wrist and a pair of ankle modules. In the system, the waist module functions as a main module, while the other modules function as local modules. The shoulder module connects with an earphone as a sound module, and consequently sends feedback signals in sound form so that the users have an authority towards their action according to the given feedback. Two type of wireless communication tools are used in the system; Bluetooth and ZigBee. Bluetooth is represented in red line, while ZigBee is represented in blue line as illustrated in Fig. 3. The operation is divided into two parts where the first part is where all the sensors in local modules collect data and process them to the main module. While processing if any error occurs then it will read data again from the sensor and will forward for processing [2].

3. Methodology

3.1 Tables Measuring Exercise Intensity

The experiment emphasizes the usage of waist and shoulder module in the coaching system. The shoulder module measures heart rate (HR) and provides feedback to user meanwhile the waist module analyzes the data from the shoulder module and concludes what type of advice to be implemented. This method uses current HR and applied them to Karvonen formula as shown in Equation 1. It is a mathematical formula to determine targeted heart rate zone which is then used to calculate EI (Exercise Intensity) of a user.

$$EI [\%] = (HR_{\text{Current}} - HR_{\text{min}}) / (HR_{\text{max}} - HR_{\text{min}}) \times 100 \quad (1)$$

Provided here, HR_{min} is the heart rate at idle phase and HR_{max} is the heart rate at intense exercise. EI shows physical exercise load of a user and keeping it in suitable EI range will lead the users to exercise effectively. Table 1 shows the relationship between EI and type of exercises.

Karvonen Formula will decide the threshold of heart rate (Thr). It is obtained by separating the threshold value between Thr_{max} and Thr_{min} into three parts. Highest separating value is referred to Thr_1 meanwhile the lowest separating value is referred to Thr_2 . For example, if Thr_{max} is 150bpm and Thr_{min} is 130bpm, the separating values are 143bpm (Thr_1) and 123bpm (Thr_2). These thresholds show the trend of heart rate which is categorized as negative or plateau, medium and positive trend. The maximum trend calculation of data acquisition for heart rate is three seconds. Index of the trend are $[HR < Thr_{\text{min}}]$, $[Thr_{\text{min}} < HR < Thr_1]$, $[Thr_1 < HR < Thr_2]$, $[Thr_2 < HR < Thr_{\text{max}}]$, $[Thr_{\text{max}} < HR]$. The trend and threshold value will be using to choose the type of advice to be given to user. Table 2 shows the relationship between the trend of

heart rate and type of advices feedback produced by the system. There is a total of six type of advices installed in the system. Table 3 shows all the six type of advices. Shoulder module measures user’s current HR and it sends data to the parameter pool of the waist module. Then, the waist module will analyze the information using data from the parameter pool. In the information processing, the shoulder module compares current HR with threshold values. As a result, the module will decide what type of advices should be produced. When the user applies the arm gesture mode during the running, the waist module will trigger the shoulder module to recalculate and reproduce advice to the user.

Table 1 - Relationship between exercise intensity and type of exercises

Exercise Intensity (%)	Type of Exercises
Less than 50	Light training (walking)
50-60	Medium training (slow running)
60-85	Stressed exercise (hard training)
85-100	Heavy exercise (professional level)

Table 2 - Relationship between trend of heart rate and type of advices

Trend of HR	Negative/Plateau	Medium	Positive
HR < Thr _{min}	Advice 1		
Thr _{min} < HR < Thr ₁	Advice 1	Advice 2	Advice 3
Thr ₁ < HR < Thr ₂	Advice 2		
Thr ₂ < HR < Thr _{max}	Advice 2	Advice 4	Advice 5
Thr _{max} < HR	Advice 6		

Table 3 - Type of advices

Type of advice	Advice contents	Advice color
1	Pace up slowly	
2	Keep pace	
3	Pace down slowly	
4	Pace down	
5	Pace down quickly	
6	Stop exercise now	

3.2 Arm Gesture Mode in Wrist Module

Arm gesture mode is a new application of the coaching system. Z-axis of accelerometer on wrist module is assigned to be arm gesture axis of the advice. In other words, when Z-axis of accelerometer in wrist module is equal to 1G, the module will trigger feedback function in sound module to produce new advice for the user. User who uses exercise monitoring system with advice feedback function in daily exercise is able to control the system in ways that benefits themselves. The feedback function has become a better system with application of wrist module as arm gesture detection function.

Fig. 4 shows the axial bearing of accelerometer sensor in wrist module at standing position. Based on Fig. 4, different position produces different axial value. When the user’s hand position is at horizontal position, this is where the bearing of Z-axis of accelerometer sensor equal or nearly equal to 1G.

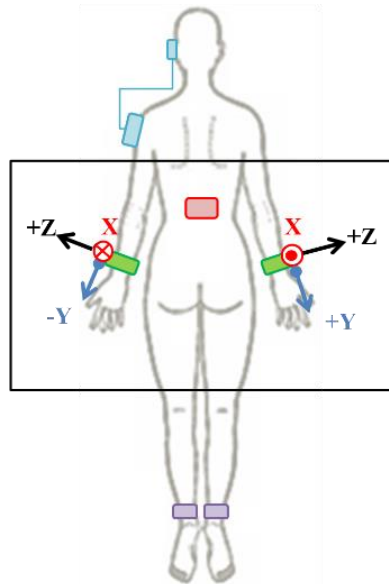


Fig. 4 - Axial Bearings in Arm Gesture Mode

3.3 Experimental Condition

In this experiment, waist, shoulder and a pair of wrist modules are attached to some part of a male body. He is a 22 years old athlete, 162cm of height and 57kg of weight. The athlete was not supervised during the first 10 minutes of the running, afterward the athlete was supervised by the coaching system for 10 minutes. During the supervised stage, the athlete is required to listen to the advice given by the coaching system and ran accordingly. At this phase, the athlete was able to use arm gesture mode at any time to get preferred feedback. Fig. 5 shows time acquisition of the whole experiment. The running was conducted in an outdoor stadium.

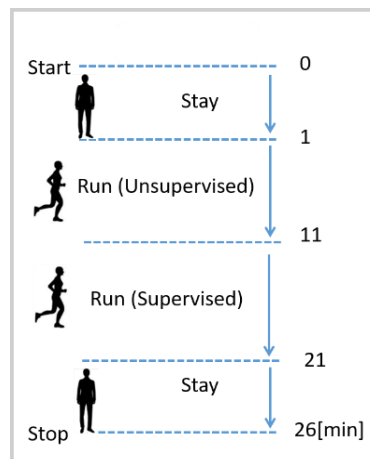


Fig. 5 - Time Acquisition in Running Exercise

4. Result and discussion

Fig. 6 shows the pattern of heart rate for the whole running exercise. The greater the heart rate infiltrated in the threshold area, the greater the percentage of the threshold. It will consequently boost the training performance. The athlete presents excellent results in terms of exercise performances in supervised training. Fig. 7 shows the result of unsupervised running. The percentage of threshold area infiltrated during the unsupervised running is about 3% of the heart rate, while the percentage increases to 87% when changed to supervised running as shown in Fig. 8. Increasing in 84% shows a great improvement in exercise performance done by the athlete. At the end of the experiment, the athlete completed the running without facing fatigue problem. The feedback function has become a better system with application of wrist module as arm gesture mode. Based on the experimental result of the arm gesture mode, the athlete applied the arm gesture mode for 9 times within the 10 minutes of running. The mode helps the athlete to perform better during exercising.

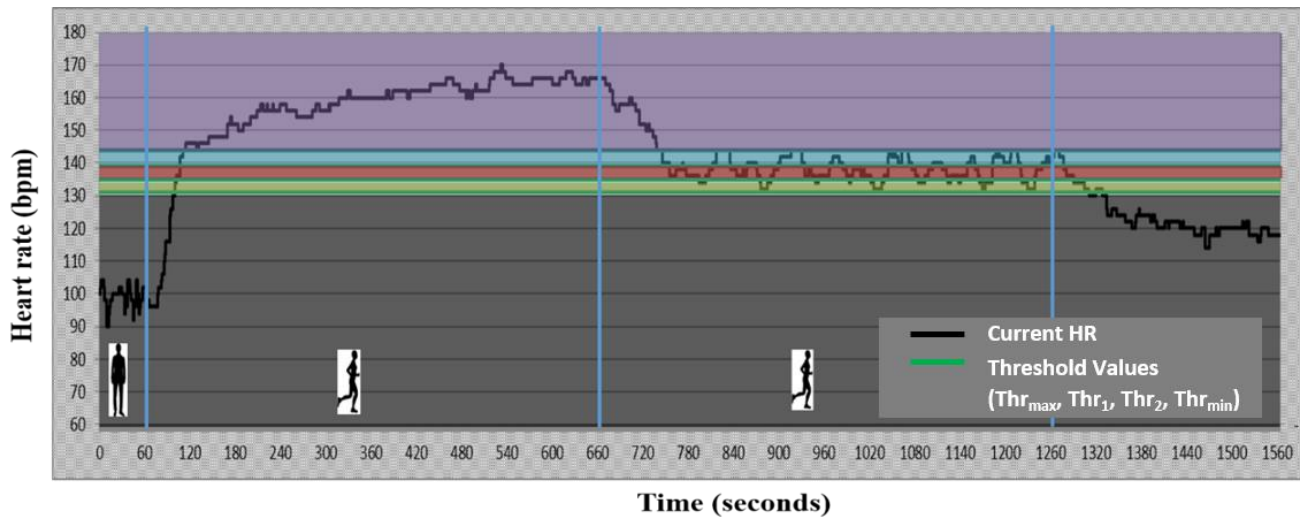


Fig. 6 - Result of Heart Rate in Whole Coaching Exercise

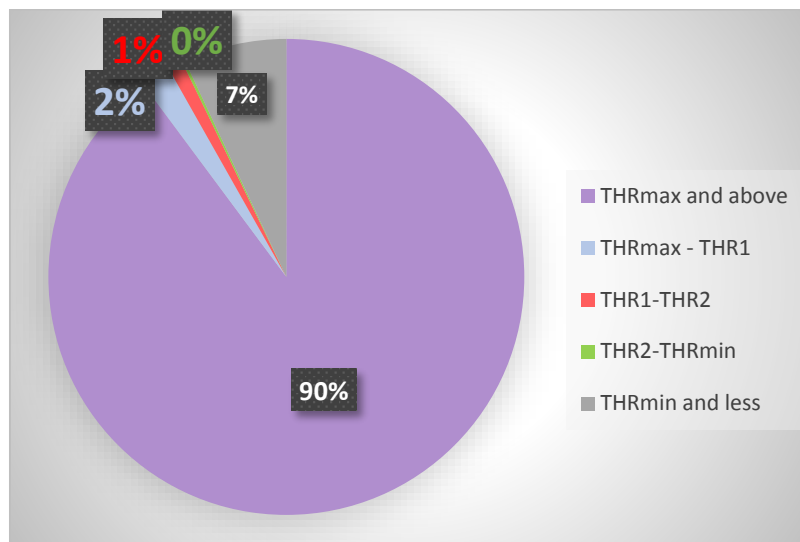


Fig. 7 - Percentage of Infiltrate Heart Rate During Unsupervised Exercise

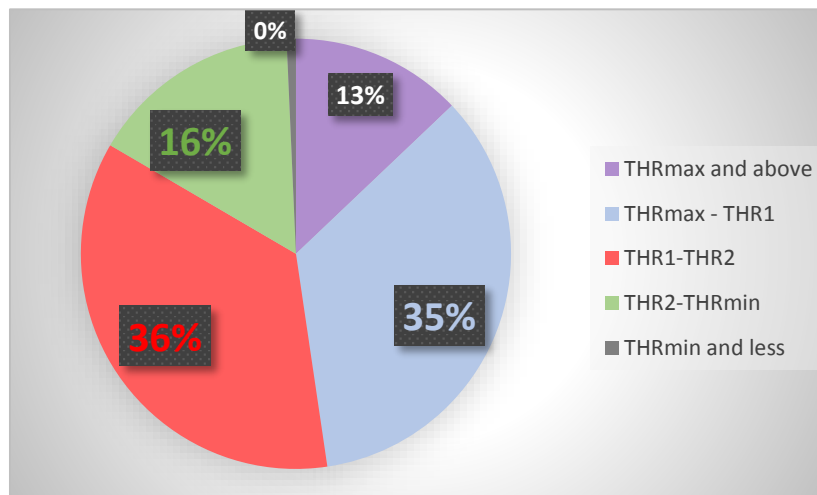


Fig. 8 - Percentage of Infiltrate Heart Rate During Supervised Exercise

5. Conclusion

In this paper, a wearable coaching system is designed to help athlete to perform efficient exercise suitable to one's body needs. It measures the parameter of the body, analyze and provide feedback in a form of an advice. Arm gesture mode performed by the wrist modules is proven a vital assistance to the wearable coaching system. This mode enables athlete to manage their exercising level to a more appropriate pace, suitable with their individual body by reproducing the feedback. In a supervised coaching training, percentage of heart rate threshold target is increasing, hence, producing a greater performance of training. It is proven in this paper, that wearable coaching system with an additional of arm gesture mode could enhance sports and training performance.

Acknowledgement

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