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Research Article

FITNESS MONITORING SYSTEM WITH RASPBERRY PI PICO

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Abstract

Diabetes has become an accepted curse in society. Sophisticated lifestyle and work from home situations have ended up making people have the least consciousness of their physical wellbeing. Hence, health monitoring has become the need of the hour. But monitoring fitness is one of the cumbersome tasks to attain mental and physical wellness. In this paper, an inexpensive but effective fitness monitoring system is developed. Unlike the existing models, this system uses user input and a single Pulse-Oximeter sensor to analyze eight significant health parameters that need to be accounted to have sound health. The Parameters include BPM of Heart, Oxygen Saturation in Hemoglobin, Relative Fat Mass, Maximum Heart Rate, Heart Rate Reserve, Target Heart Rate, Resting Metabolic Rate and Daily Energy Expenditure. This model is implemented using Raspberry Pi Pico microcontroller. The unique data logging feature of Pi Pico is used for storing the computed data without additional peripherals. This data is further analyzed by connecting it to the computer as when required. The memorized data is analyzed using the GNU Octave open-source Visualization tool. To add to the advantage of this model, it is an unwearable device that does not require to be in contact with skin or body continuously to monitor the parameters.

Keywords: Fitness, Raspberry Pi Pico, Data logging, Max30100 Pulse-Oximeter, Heart Rate, SpO2, Daily Energy Expenditure.

INTRODUCTION

Regular exercising escalates amour propre in humans and impedes raised levels of anxiety. A 40-minute regular exercising facilitates a considerable balance of Serotonin in the brain [1]. The advancement in technology has given birth to wearable devices for fitness monitoring. The wearable fitness trackers include fitness bands, smartwatches and smartphones. These health monitors are affordable compact accessories for personal health screening. They are extensively used for tracking the pressure in the blood, the rate of respiration, body temperature, oxy-hemoglobin concentration and the calories burnt per diem [2]. The present-day technology facilitates the fabrication of such health screening systems on compact and flexible materials. The optoelectronic sensors are light weight elastomeric substrates that easily fasten with human skin and enable uninterrupted tracking of health [3]. Commercially available fit-bands are water-proof wrist accessories that are worn all day for figuring out the sleep patterns and sleep parameters. It is a low cost- biomedical development for Polysomnography. Though its effectiveness is not proven to be unparalleled with the standard clinical apparatus, it is largely purchased to have an elementary awareness of one's health [4]. Heart beat rate is a significant criterion for determining fitness. A pulse sensor is interfaced with Arduino Uno microcontroller to determine heartbeat. A Wi-Fi module is wired with the Uno controller to send the data to the cloud for analyzing the age-based criteria of male and female heart rates. An android application is built to access the heartbeat data at all times. In this signal processing, the Fast Fourier Transform Algorithm (Butterfly method) is chosen to be an efficient way to extract the pulse signals [5]. As an implementation of Internet of Things, Arduino microcontroller is made to communicate with Raspberry Pi to detect abnormalities in health on the basis of electrical activity, rhythm, beat of heart and body temperature. If any unsolicited health record is sensed, an immediate report of the same is sent to the hospital and the guardian. As an improvisation in validating this undesired hiccup in any of the health parameters, the location along with the photographs is sent using the Global Positioning System Module [6]. Raspberry Pi Pico is a dual core microcontroller with a 12-bit ADC and a real-time counter. With the RP2040 chip, it works at 3.3 volts and runs on Micro Python. Its computation is quicker than Arduino Uno microcontroller. Its Phase Controlled Loop enables altering of its core frequency to suitable levels as required by the application. Raspberry Pi Pico is a new development board that can be used efficiently in various streams of research and development [7]. The MAX30100 module is a frequently used implementation of Photoplethysmography. It enables sensing of heart rate along with pulse oximetry. Powering this module is a plain sailing method as it works at 1.8 volts and 3.3 volts. With low noise analog signal processing, it is a compact low-power oximeter module. This module is interfaced with a BLE chip to transmit the data wirelessly through Bluetooth to a smartphone at a rate of 100 samples per second [8]. The accuracy of MAX30100 sensor for pulse rate is 97. 11 percent. For oxygen saturation, it has high level of accuracy up to 98.84 percent. It is reliable for the identification of abnormalities in breathing. It is one of the non-invasive methods for finding oxygen saturation [9,10]. The combination of NodeMCU microcontroller and MAX30100 oximeter module eases unfaltered data collection of oxygen saturation level in COVID patients. Adding a power backup, the setup becomes a standalone health monitor that displays the data on the screen and sends it to the server in parallel. This data can further be accessed anywhere, anytime by accessing the server. The values collected using the oximeter module tend to be more accurate as when compared with market available systems [11]. Fitness monitoring in a professional environment (gymnasium) can be ensured by assessing the workouts carried out by the trainee. Assessments can be automated by affixing sensors in the equipment to estimate the extent of exercising. An improper exercise invites multiple complexities in the body.

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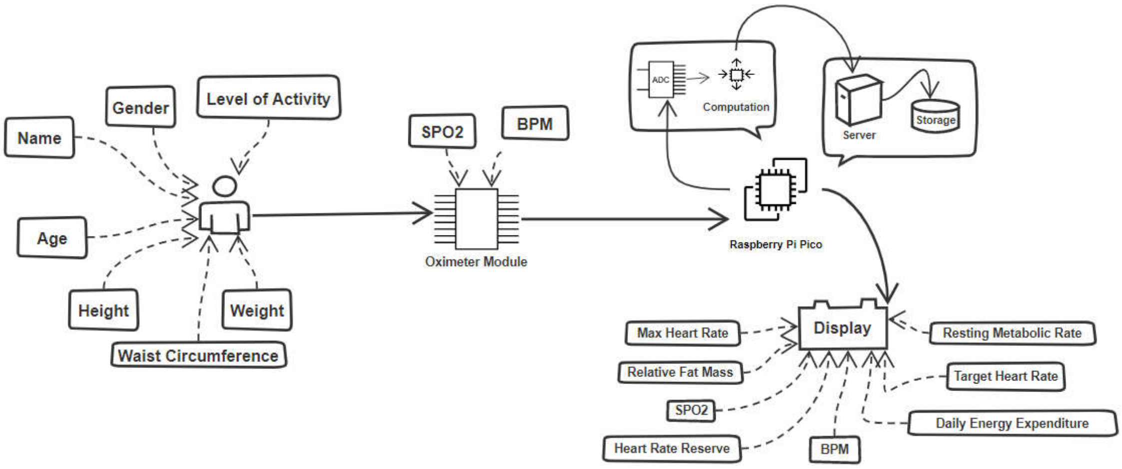

Fig. 1. Sequence Diagram of the Proposed system

Using Arduino Nano, the sensor data from the equipment is merged with each trainee's local RFID and it is memoized. With this approach, effectiveness in the physical fitness process is ensured [12].

METHODOLOGY

The system is modelled to begin its execution by initializing basic health information of the user. The input parameters include name, age, gender, height, weight, waist circumference and level of activity. In accordance with the level of activity selected, the system calibrates itself to compute the output parameters in one of the three modes viz., Minimum, Moderate and Maximum. The MAX30100 pulse-oximeter module is connected with the microcontroller to send the oxy-hemoglobin saturation level and Heart Beat Rate to the RP2040 chip in the Pico board. The Max30100 module works using the principle of variation in absorption of light by the oxygenated and de-oxygenated blood in the body. Further, with the input values and sensor data, Maximum Heart Rate, Relative Fat Mass, SpO_2(Oxy-hemoglobin level), Heart Rate Reserve, Target Heart Rate, Current Heart Beat Rate (BPM), Resting Metabolic Rate and Daily Energy Expenditure are computed. The parameters are displayed to the user with an OLED display. In addition, the data is logged into the Pico microcontroller board. This facilitates simple data accessing when required. A post-exercise screening is done to check if the target heart rate is achieved. If the target heart rate is not reached, the system using the latest logged data, displays the remaining time to work-out for achieving the target heart rate. Fig.1 shows the working of the designed model.

Parameters

BPM: Heart Rate / Pulse which is commonly known as BPM (Beats Per Minute) is the number of times a human heart beats every minute. BPM plays a prime role in determining health of a person. It helps in identifying Arrhythmia, Tachycardia and Bradycardia. A healthy heart should have a consistent rate between 60 and 100 in its pumping. Age, Circadian Rhythm, Physical Diseases, Psychiatric diseases and work-lifestyle directly impact the rate of pumping in the heart [13, 14, 15, 16].

SpO_2 : Oxygen saturation is the percentage of oxygen-bound hemoglobin present in the blood. The healthy range of Oxygen Saturation is from 95 percent to 99 percent. The conventional method for measuring SpO_2 is the transmissive pulse oximetry [17].

Relative fat mass: Relative Fat Mass measures the amount of undesired fat in the body. Relative Fat Mass requires height and waist circumference of a person as parameters to calculate obesity. The accuracy of Relative Fat Mass is maintained by using unsimilar equations for two different age groups and genders [18, 19].

Maximum heart rate: Maximum Heart Rate is the highest rate at which one's heart beats. Maximum Heart rate in humans varies with age. It is calculated by taking age as a parameter. It is one of the crucial factors that has to be accounted during exercising. It interprets the target heart rate [20].

Heart rate reserve: Heart Rate Reserve is reserve rate of heart that is calculated as the difference of the maximum heart rate and resting heart rate. It defines the range of pulse that is available for exercising [21].

Target heart rate: Target Heart Rate is a free-hand parameter opted by the user. It is the heart rate that is aimed to be achieved during exercising. It works in three levels of intensities i.e., Minimum, Moderate and Maximum. The number of calories burnt banks on the target heart rate [22, 23].

Resting metabolic rate: Resting Metabolic Rate is the number of calories burnt during rest. When a person is at rest completely, some calories are burnt by the functioning of internal organs, blood oxygenation and de-oxygenation and by some neurological functions [24, 25, 26].

Daily energy expenditure: Daily Energy Expenditure is the total number of calories burnt by a person per day. It is influenced by exercising, Resting Metabolic Rate (RMR), Thermic Effect of Food (TRF), Excess post-oxygen consumption and non-exercise activity thermogenesis (NEAT) [27, 28].

Hardware

To test the proposed idea, a Raspberry Pi Pico microcontroller, MAX30100 Pulse-Oximeter Module, SSD1306 Optical Light Emitting Diode Display are used. The setup is carried out using Inter-Integrated Circuit Protocol. The Oximeter module and the OLED display are powered from the 3.3v source of the Pico board. For the serial communication between the modules and the microcontroller, two pairs of SDA and SCL ports are used. Serial Data pin and Serial Clock pin of the Oximeter module are connected to Pin 31 and Pin 32 of the microcontroller board respectively. Similarly, The OLED Display's Serial Data and Serial Clock ports are correspondingly connected to Pin 21 and Pin 22 of the Pico Board. The usage of such General-Purpose pins in the microcontroller for interfacing modules is not restricted to the circuit as shown in fig. 2. As the Pico microcontroller comes with multiple pairs of SDA and SCL pins for Inter-Integrated Circuit Communication, one of the multiple pairs can be used. Further, the pins used must be declared explicitly in the code before execution.

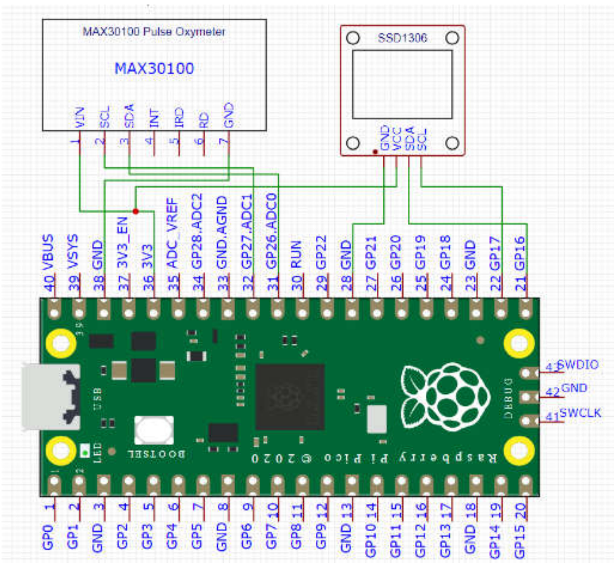

Fig. 2. Circuit diagram to interface Raspberry Pi Pico with Max30100 module and SSD1306 OLED display

Software

The Raspberry Pi Pico microcontroller is loaded with MicroPython and it is coded using Thonny IDE. An algorithm is developed for the intended design.

Let N, A, G, H, W, WC, AL, SpO_2, BPM, RFM, MHR, THR, RMR, DEE represent Name, Age, Gender, Height, Weight, Waist Circumference, Activity Level, Oxygen Saturation, Beats Per Minute, Relative Fat Mass, Maximum Heart Rate, Target Heart Rate, Resting Metabolic Rate and Daily Energy Expenditure respectively.

Algorithm 1:

1. **Input** LocalTime, N, A, G, H, W, WC, AL from user
2. **Start** LocalTime
3. **Read**SpO_2 and BPM from oximeter
4. **Start** Timer
5. If A > 14 AND G == Male:
6. **Compute** RFM as sum of 64, and quotient of -20 times of H and WC
7. If A > 14 AND G == Female:
8. **Compute** RFM as sum of 76 and quotient of -20 times of H and WC
9. If A > 8 AND A < 14 AND G == Male:
10. **Compute** RFM as sum of 74 and quotient of -22 times of H and WC
11. If A > 8 AND A < 14 AND G == Female:
12. **Compute** RFM as sum of 79 and quotient of -22 times of H and WC
13. **Compute** MHR as difference of 207 and product of 0.7 and A
14. **Compute** HRR as difference of MHR and BPM
15. **Compute** BaseRMR as sum of 9.9 times of W and 6.25 times of H and difference of 4.92 times of A.
16. If G == Male:
17. **Compute** RMR as sum of BaseRMR and 5
18. If G == Female:
19. **Compute** RMR as difference of BaseRMR and 161
20. If AL == Min:
21. **Compute** THR as sum of BPM and product of 0.5 and HRR
22. **Compute** DEE as 1.2875 times of RMR
23. If AL == Mod:
24. **Compute** THR as sum of BPM and product of 0.7 and HRR
25. **Compute** DEE as 1.55 times of RMR
26. If AL == Max:
27. **Compute** THR as sum of BPM and product of 0.85 and HRR
28. **Compute** DEE as 1.8125 times of RMR
29. **Store** and **Display** BPM, SpO_2, RFM, MHR, HRR, RMR, THR, DEE
30. **Delay** Until Sensor data is found
31. **Read** data from Oximeter
32. **Stop** Timer
33. **Display** Timer
34. **Display** BPM, SpO_2
35. If (BPM < THR)
36. **Display** Pending as difference of THR and BPM
37. **Delay** until Sensor data is found
38. **Read** data from oximeter
39. **GOTO** Step 38
40. **Display** "Target Reached"

Data logging and the dual core: Logging user data and sensor data is a unique feature of Raspberry Pi Pico. Unlike the Arduino, ESP32 and NodeMCU microcontrollers, Pico does not require an external Secure Digital card to store data. Neither does it require a Wi-Fi Connectivity to store data in the cloud. Though the cloud service is emerging at its full swing in every sector, cloud storage becomes essential only with the implementation of a health monitoring system that stores the prime health data about a patient, which needs to be available at the click of the button. In the fitness monitoring system, which is just used as a fitness assistant, the data is not necessarily required to be available online. Sending data to the cloud is a resource consuming process and it is expendable. Still, the data needs to be stored for reviewing self-fitness. Pico board uncomplicatedly addresses and accomplishes this task. The Pico microcontroller works on MicroPython, a flavor of Python Programming. Python facilitates easy creation, appendage, modification, storage and deletion of files. With this approach, the user data along with pre-exercise and post-exercise health data is saved as a CSV (Comma Separated Values) file. This CSV file is created for each user and for every user login, the corresponding data is sensed and the computed data is appended to the file. The data is initially computed with the primary core. As the data gets processed, it is stored in the controller using the Auxiliary core (second core) thereby the job is distributed. This distribution is done so as to provide room for the internal clock to start as soon as the pre-exercise data is fetched. In this way, data storage becomes simple and power-efficient.

Time stamp: Accurate data collection is enhanced with timestamps. To match the timestamp with local time, either the microcontroller has to be connected to internet or it can be achieved using time functions of MicroPython. Since the proposed model is not aimed to work with the internet, the local time is maintained by initializing the clock every time the board is powered. In addition, to store the total workout time, the internal clock of the Pico board is used.

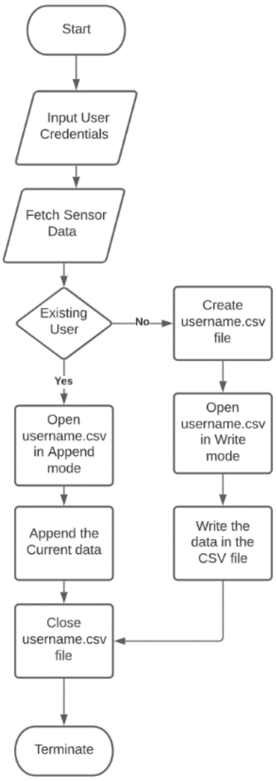

Fig. 3. Flow diagram of the working of data logging to create, write, append and store user data as CSV file

Fig. 3 shows the customized process of data logging in Raspberry Pi Pico microcontroller. The data is first fetched from the user. The user details are verified with the data in the database of the microcontroller. If the entered user data matches with the database, the particular file is opened in 'Append Mode' to log the current data. If the data entered by the user does not match with the database, a new CSV file is created. Once the data is fed, it is automatically added to the database.

RESULTS AND DISCUSSION

This Model was prototyped and it was rigidly tested by six users of different age groups. The prototype testing was carried out by each user for five days. The testing was assessed based on the factors that include the robustness of the Pico microcontroller, its accuracy in data logging, accessing data, easy deletion of data from the database and exporting the logged CSV file to Octave Visualization Tool for analysis. The users experienced smooth working of the design. The users were able to log data multiple times a day without any hiccup. Unless the power was turned off, the Pico board maintained an accurate local time. In addition, the standard baud rate of the microcontroller i.e., 115200 along with its 133 MHz clock speed, and dual core for data collection, data processing and storage tended to be a cost-effective and constructive combination for designing the model.

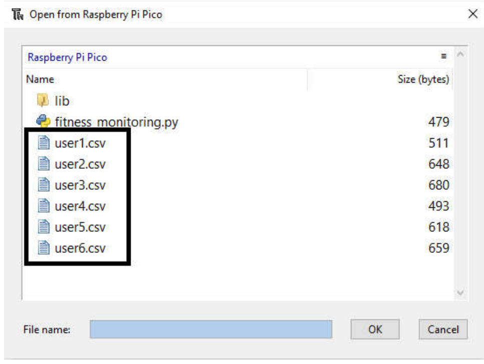

Fig. 4. User data stored as CSV files in the Pico board

Fig. 4 shows the CSV files of the logged data. This easy-essence of Python programming in MicroPython flavor is effectively used in this model. This has significantly reduced the resource utilization for data storage and can be considered as an economic replacement for Wi-Fi enabled microcontroller boards.

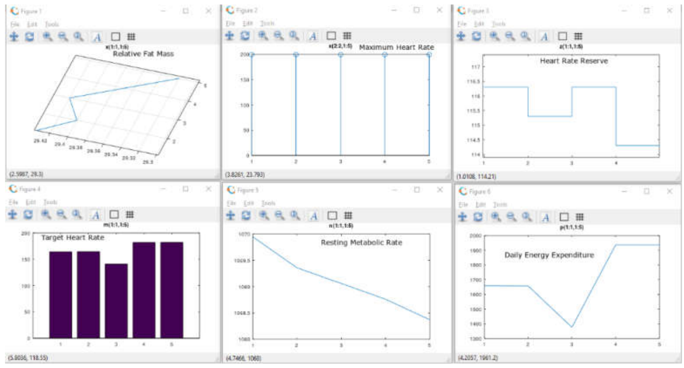

Fig. 5. Octave Visualization for User data

Fig. 5 shows an example of analyzing all the mentioned fitness-related parameters using Octave. As the raw data is fetched and is imported as CSV, the user can analyze it as required. In the figure, the user has analyzed each parameter at the end of the fifth day. The user has used Line graph, Bar graph, Stair graphing and Stem graphing for the analysis. Displaying of multiple individual graphs in the single screen enabled effortless interpretation of data.

Fig. 6 and fig. 7 are the bar graphs of auser's Heart Beat Rate and Oxygen Saturation level before and after each day's exercising. This enabled the user to easily understand the fitness and it created a noticeable self-awareness in the user about many unaccounted but significant fitness parameters that impacts the well-being of the people. This design also includes the Daily Energy Expenditure parameter that is widely seen in any commercial fitness trackers.

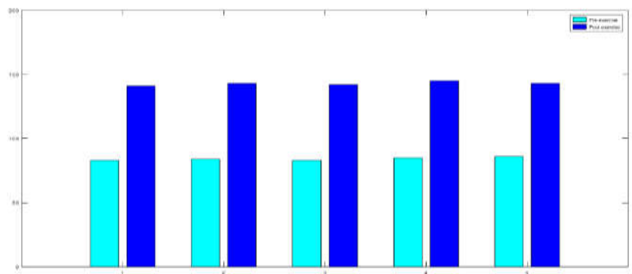

Fig. 6. Logged heart beat rate before and after exercising for five consecutive days

Cyan colored bars represent data collected before exercising and Blue colored bars represent the heart beat rate after exercising.

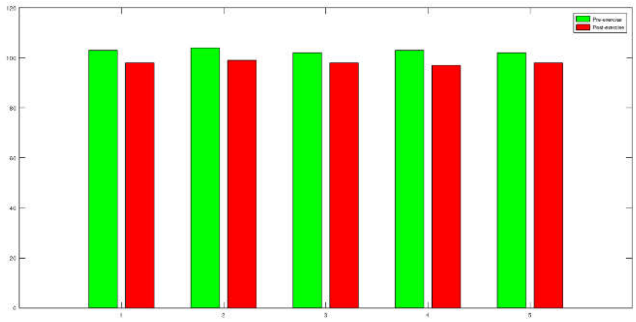

Fig. 7. Logged oxygen saturation data before and after exercising for five consecutive days

Green colored bars represent oxygen saturation data collected before exercising and Blue colored bars represent the oxygen saturation level after exercising.

Conclusion

Fitness Monitoring using Raspberry Pi Pico is a new approach to screen a person's fitness-based health parameters. The proposed model does not require any internet connectivity to log data. Multiple fitness parameters are computed using user input and Oximeter sensor values. This replaced the need for using multiple power-consuming sensors. As the data is logged in the board, it can be accessed easily as a CSV file by connecting it to any computer. As numerous parameters are introduced in the proposed design which are generally not available in the commercial products, the system design is proven to be technically informative.

Future Work: This model can further be connected to a dedicated power supply to provide uninterrupted power to the board during power shut-downs. A precise real-time clock module can be interfaced with the Pico board to maintain the time even when the controller is turned off.

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