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Cost-Effective and Portable Heart Rate Monitoring System using Arduino Uno and Fingertip Sensor

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ABSTRACT

The continuous monitoring of heart rate is essential for individuals with cardiovascular conditions and those engaged in fitness activities. However, existing heart rate monitoring systems are often costly and lack portability, limiting their accessibility in low-resource settings. This paper presents the design and implementation of a cost-effective and portable heart rate monitoring system using Arduino Uno and a fingertip sensor. The proposed system aims to provide an affordable solution for real-time heart rate monitoring, combining the simplicity of the Arduino platform with the precision of optical heart rate sensing technology. Testing was conducted on two different generations under resting conditions: an adult aged 40 years who works as a lecturer and a child aged 2 years. The results showed that the average BPM for the adult was 73.3 BPM, while the child had an average BPM of 92 BPM. Performance evaluations indicate that the system delivers reliable heart rate readings within the normal range for various user profiles, demonstrating its potential as a viable alternative to more expensive commercial devices.

1. Introduction

Heart rate monitoring is a critical component of healthcare, serving as a fundamental indicator of cardiovascular health [1,2]. The heart rate, expressed in beats per minute (BPM), reflects the heart's efficiency in pumping blood throughout the body [3,4]. Abnormal heart rates, whether too high or too low, can signal underlying health issues such as arrhythmias, heart disease, or even imminent cardiac events [5]. Regular monitoring allows for early detection of these conditions, enabling timely medical intervention and potentially preventing serious complications [6].

For individuals with chronic health conditions like hypertension, diabetes, or heart failure, continuous heart rate monitoring is indispensable [7,8]. It provides real-time data that helps in adjusting treatments, managing daily activities, and preventing adverse health events [9,10].

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Moreover, in the context of fitness, monitoring heart rate during exercise ensures that individuals stay within safe exertion limits, optimizing their workouts while avoiding overexertion [11,12]. This dual role of heart rate monitoring both in clinical management and in maintaining physical fitness underscores its importance in everyday health practices [13,14].

In many regions with limited access to advanced healthcare facilities, cost-effective and portable heart rate monitoring systems are particularly valuable [15,16]. These systems empower individuals to monitor their heart health at home, promoting preventive care and reducing the strain on healthcare resources [17,18]. As telemedicine and remote patient monitoring become more prevalent, reliable heart rate monitoring tools are essential for enabling continuous care [19,20]. Thus, developing accessible and affordable monitoring systems, such as those utilizing Arduino technology and optical sensors, is crucial for making healthcare more inclusive and effective.

Many literatures studied of heart monitoring system such as Arulananth and Shilpa [21] elucidated a methodology for quantifying the heart rate *via* a fingertip sensor integrated with Arduino, founded on the principles of PPG, which constitutes a non-invasive approach to assess fluctuations in blood volume within tissues by employing a light source and a detector. Pawar *et al.,* [22] conducted a monitoring study of physiological parameters, such as heart rate, and transmitted the collected data directly to a medical practitioner *via* SMS. The system is comprised of an infrared-based heart rate sensor, an Arduino Uno microcontroller, and a GSM communication module. Aarthi *et al.,* [23] elucidated the PPG signal obtained from human subjects utilizing a data acquisition system comprised of an Arduino board in conjunction with a Maxim Integrated sensor. Subsequently, signal processing methodologies were employed to eliminate baseline drift, mitigate motion artifacts, and execute signal filtration for peak detection via an algorithm formulated in MATLAB. Devis *et al.,* [24] developed a comprehensive monitoring system that continuously tracks three critical health parameters heart rate, body temperature, and intravenous fluid usage in hospitalized patients. The system is designed not only to monitor these parameters in real-time but also to provide an audible warning in case of any abnormalities, thereby ensuring timely medical intervention. Sagar and Aradhya [25] designed system that remotely monitors heart rate and dynamically plays music based on the detected heart rate to enhance exercise regimes. By integrating a pulse sensor with an Arduino Ethernet shield, the system enables real-time remote monitoring of heart rate through a web interface. Mukherjee *et al.,* [26] implemented wireless heart rate monitoring system using Arduino Lilypad that can send SOS messages or make calls through a GSM module when abnormal heart conditions are detected. It consists of a transmitting circuit, worn by the patient, and a receiving circuit for data processing. Chooruang and Mangkalakeeree [27] developed heart rate monitoring system using the ESP8266 Wi-Fi module integrated with an Arduino microcontroller and the MQTT protocol for lightweight, real-time communication. The system aims to remotely monitor a patient's heart rate by utilizing infrared light and a photodetector to capture the heartbeat signal and transmit the data wirelessly to an MQTT broker running on a Raspberry Pi.

The contributions of this paper are multifaceted, addressing both technological innovation and practical healthcare applications. Firstly, the paper introduces a cost-effective and portable heart rate monitoring system using Arduino Uno and a fingertip sensor, providing an affordable alternative to existing commercial devices. By leveraging the simplicity and versatility of the Arduino platform, the system is designed to be easily replicated and utilized in various settings, particularly in low-resource environments where access to advanced healthcare technologies is limited. Secondly, the paper offers empirical data on the system's performance, tested on two different age groups under resting conditions. This not only demonstrates the system's accuracy and reliability across different user profiles but also underscores its potential for widespread adoption in both clinical and personal health monitoring. Lastly, the paper contributes to the ongoing development of accessible healthcare technologies by highlighting the system's advantages, discussing its limitations and suggesting future enhancements that could further improve its efficacy and usability.

2. Methodology

2.1 Overview of the System Architecture

The proposed heart rate monitoring system is designed to be a cost-effective and portable solution for real-time heart rate tracking, utilizing the Arduino Uno microcontroller as the core processing unit. The system architecture is composed of three primary components: the input sensor, the processing unit, and the output display. The input sensor, a fingertip optical heart rate sensor, detects the pulse signal from the user's finger. This signal is then transmitted to the Arduino Uno, where it is processed to calculate the heart rate in BPM. The processed data is subsequently displayed on an LCD screen, providing immediate feedback to the user. Additionally, the system is designed to be compact and portable, making it suitable for both clinical and personal health monitoring applications.

2.2 Description of the Hardware Components

Based on the Figure 1, The pulse sensor is connected to the Arduino Uno via three wires: VCC, GND, and signal output. The signal output from the pulse sensor is fed into one of the analog input pins on the Arduino for processing. The Arduino Uno is also connected to an LCD display through four wires: VCC, GND, and two data lines (SDA and SCL) for communication. This configuration allows the Arduino to read the pulse sensor data, calculate the heart rate, and then display the BPM on the LCD screen in real time, providing an immediate visual representation of the user's heart rate.

The following components are essential for constructing a heart rate monitoring system:

i. Arduino Uno: The Arduino Uno is a microcontroller board based on the ATmega328P, which serves as the brain of the heart rate monitoring system. It is responsible for processing the pulse signal received from the fingertip sensor, calculating the heart rate, and managing the data display on the output screen. The Arduino Uno was chosen for this project due to its ease of use, affordability, and widespread availability. It provides sufficient processing power to handle the real-time data from the sensor while also offering multiple input/output pins for interfacing with other components, such as the LCD display.
ii. Fingertip Heart Rate Sensor: The heart rate sensor used in this system is an optical pulse sensor designed to be placed on the fingertip. It operates by emitting a small amount of infrared light into the finger and measuring the light that is reflected. As blood pulses through the finger, the amount of reflected light varies, allowing the sensor to detect the heartbeat. This signal is then sent to the Arduino Uno for further processing. The sensor is compact, non-invasive, and simple to use, making it ideal for portable health monitoring systems.
iii. LCD display: The system includes a LCD to provide a visual output of the measured heart rate. The LCD is interfaced with the Arduino Uno to display the BPM calculated from the sensor data. This real-time display ensures that users can immediately see their heart rate, making the system both informative and user-friendly. The LCD was selected for its low power consumption and clear readability, which are essential for a portable device.

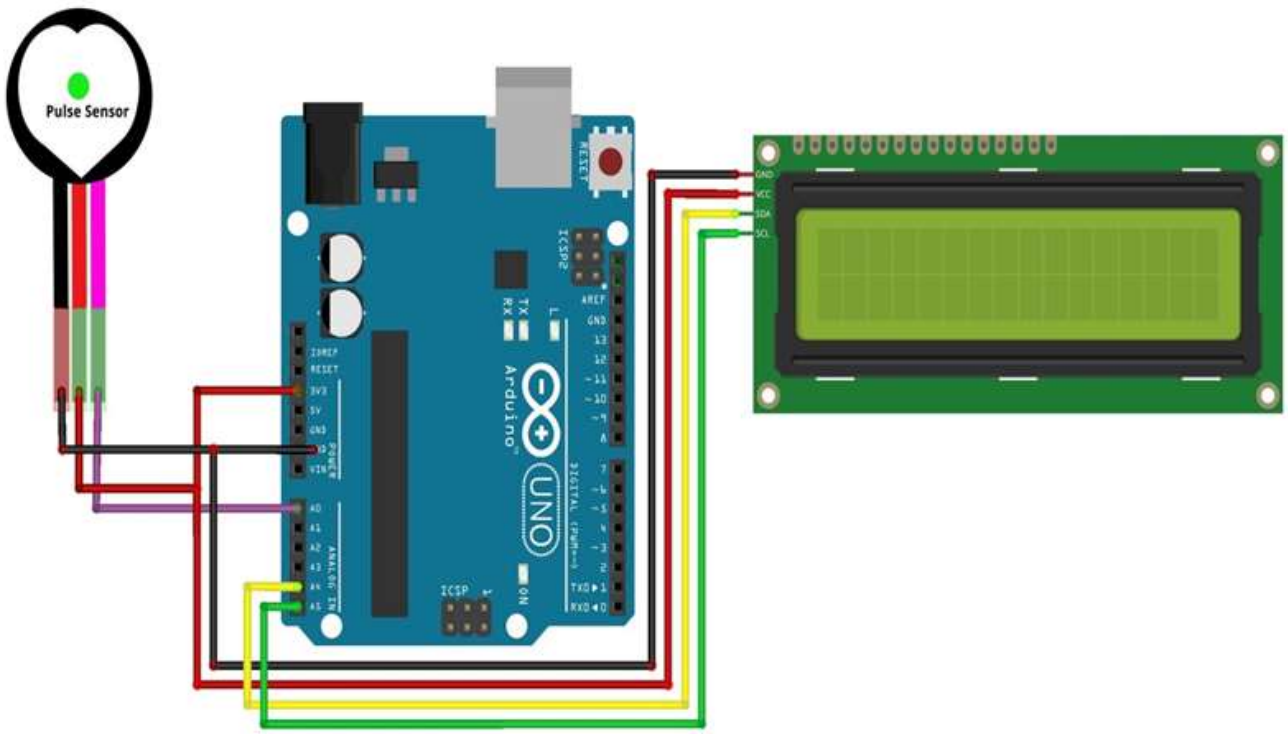

Fig. 1. Pulse sensor Arduino connection

In this study, this research requires several components to realize it both hardware and software as in Table 1.

Table 1
Research components

No.	Components	Quantity
1	Arduino UNO Board	1
2	Laptop/PC	1
3	Jumper Cables	1
4	16X2 I2C LCD Display	1
5	PCB	1
6	Arduino Software	1

2.3 Software Implementation

This section discusses the software implementation used for data acquisition and processing in the heart rate monitoring system. The Arduino Uno is programmed using the Arduino IDE, where the code handles the input from the pulse sensor, processes the signal to calculate the heart rate and displays the result on the LCD screen.

The code begins by initializing the necessary libraries, such as the Wire library for I2C communication with the LCD, and the LiquidCrystal_I2C library, which simplifies interactions with the LCD display. The pulse sensor data is acquired through one of the analog input pins on the Arduino. The signal is then processed to detect the time intervals between consecutive heartbeats, which are used to calculate the BPM.

In addition to data acquisition, the software is also responsible for filtering noise from the pulse sensor signal to ensure accurate heart rate readings. The processed BPM value is then sent to the LCD display for real-time monitoring. This simple yet effective code structure enables continuous and reliable heart rate monitoring, making it easy to use in various applications.

To ensure the accuracy of the heart rate signal obtained from the fingertip sensor, the system implements a basic yet effective signal filtering method using a software-based moving average filter. This filtering technique smooths out high-frequency noise and minor fluctuations caused by hand tremors or ambient light interference. The moving average is computed over a window of 10 samples, continuously updating as new data is received through the analog input.

Additionally, threshold-based peak detection is used to identify valid heartbeats. The system dynamically adjusts the threshold based on the signal amplitude to reduce false positives caused by noise spikes. The heart rate in BPM is calculated by measuring the time interval between valid successive peaks.

This approach, although simple, was chosen for its computational efficiency and suitability for real-time processing on the Arduino Uno, which has limited memory and processing power. Future enhancements may involve implementing more advanced digital filtering techniques such as Butterworth or Kalman filters if higher accuracy or more complex use cases are required.

2.4 Data Collection

Data collection in the heart rate monitoring system begins with the pulse sensor, which is placed on the user's fingertip. The sensor operates by emitting infrared light and detecting the amount of light reflected from the finger. As blood flows through the finger with each heartbeat, the reflected light intensity fluctuates, creating a signal that corresponds to the user's pulse.

This analog signal is then fed into one of the Arduino Uno's analog input pins, where it undergoes analog-to-digital conversion. The Arduino processes this digital signal to identify peaks corresponding to heartbeats. By measuring the time intervals between consecutive peaks, the system calculates the user's heart rate in BPM. This BPM value is then used for real-time monitoring and is displayed on the LCD screen, providing immediate feedback to the user.

3. Results and Discussion

Figure 2 displays a digital heart rate monitor with a reading of "73 BPM" indicating the heart is beating at 73 beats per minute. This device likely measures and displays the user’s heart rate in real time. Heart rate monitors like this are commonly used in both medical settings and for personal health tracking because they provide valuable data about one’s cardiovascular health. The reading of 73 BPM represents the number of heart beats per minute, offering insights into the user's heart function at that moment.

Fig. 2. BPM testing in adults aged 40 years

For a 40-year-old lecturer, a heart rate of 73 BPM falls within the typical range for a resting adult, which is generally between 60 and 100 BPM. Resting heart rates can vary based on several factors, including fitness level, stress, medication and overall health. A lower resting heart rate often indicates more efficient heart function and better cardiovascular fitness. In this context, a heart rate of 73 BPM suggests that the lecturer's heart is functioning normally, assuming they were at rest when the measurement was taken.

Figure 3 shows a heart rate monitor with a digital readout that states "92 BPM" the user's heart rate is 92 beats per minute. A heart rate monitor is a device used to measure the frequency of contractions of the human heart, which is normally expressed as BPM. What is being shown is the number of beats going on right now for the person using the device. A heart rate monitor in this regard can be applied to check the pulse of a young child, say 2 years old.

Fig. 3. BPM testing in child aged 2 years

A normal resting heart rate for such an age group would range from 80 to 130 BPM. The reading is 92 BPM, which is within that range. Hence, it suggests that the child's rate is normal for his age. It is worthwhile to note that normally, children would present with generally higher heart rates than in an adult because of a smaller size of the heart and the increased metabolic rate. This heart rate can also vary depending on different factors such as activity, emotional state, and the presence of a health condition.

The Figure 4 shows the variation in BPM over a series of 10 tests. The X-axis represents the number of tests, while the Y-axis indicates the BPM values recorded. From the graph, it is observed that the BPM values fluctuate between 72 and 75 BPM throughout the tests. The highest point is reached in the 4th test with a value of 75 BPM, while the lowest point is seen in the 2nd and 7th tests with a value of 72 BPM. These values are within the normal range for resting heart rate in adults.

The average BPM in Figure 4 is 73.3 BPM, which is an indicator of good heart rate stability for adults. Although there are small variations from test to test, the BPM values remain consistently around this average, indicating that the heart rate monitoring system works well in detecting and recording BPM. The slight fluctuations in BPM may be caused by factors such as minor physical activity changes, stress levels, or environmental influences during testing. Overall, this graph shows that the system provides reliable results for heart rate monitoring.

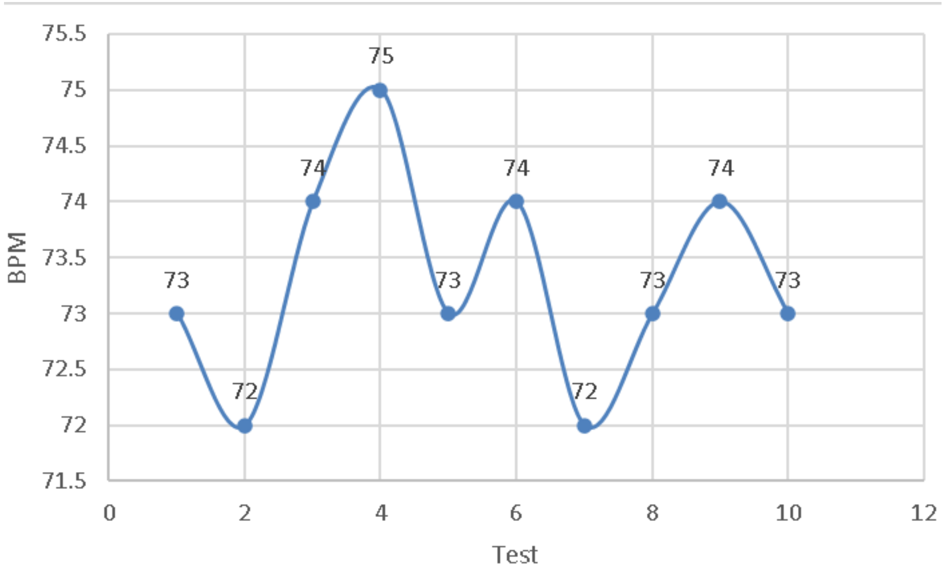

Fig. 4. Variation in BPM across repeated tests for adults aged 40 years

The Figure 5 shows BPM data measured across several trials. On the x-axis, there are numerical values representing the trial numbers, ranging from 1 to 10. On the y-axis, there are BPM values indicating the heart rate measured in each trial. The graph shows fluctuations in BPM across the trials, with both increases and decreases in BPM as the trial number progresses.

The average BPM on Figure 5 for children aged 2 years is 92.2 BPM. This means that the BPM recorded in the graph fluctuates around the 92.2 mark. This value indicates the average heart rate per minute that is normal for children aged 2 years, although there are some variations seen in the graph. For example, there is a sharp increase around trial 7 and a decrease in trial 9, which might indicate responses to physical activity or other conditions.

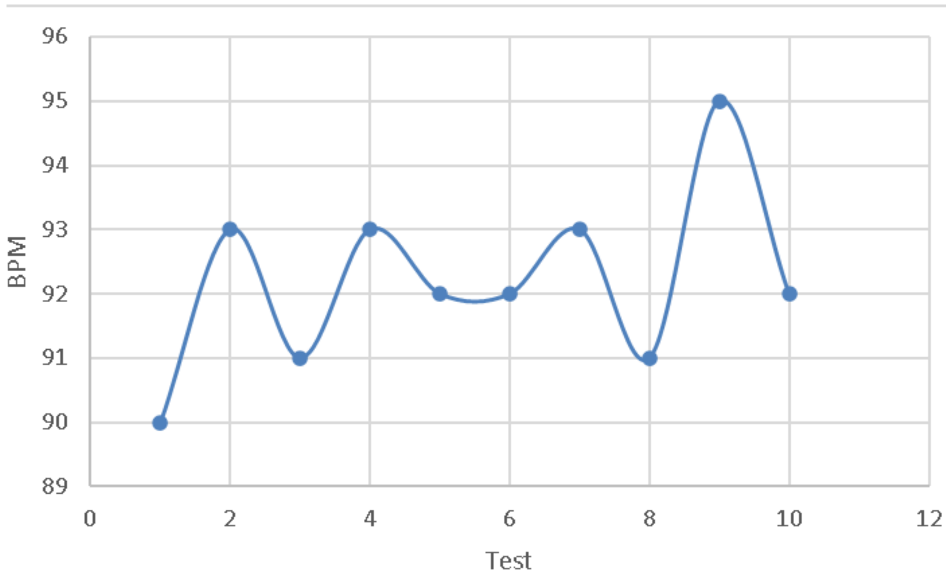

Fig. 5. Variation in BPM across repeated tests for child aged 2 years

3.1 Statistical Analysis of BPM Data

To evaluate the consistency and reliability of the heart rate monitoring system, a statistical analysis was conducted on the BPM values obtained across multiple trials for both the adult (aged 40) and the child (aged 2). Each participant underwent 10 repeated measurements under resting conditions.

i. Adult (40 years old):
Mean BPM = 73.3
Standard Deviation (SD) = 1.16 BPM
95% Confidence Interval (CI) = [72.6, 74.0] BPM

ii. Child (2 years old):
Mean BPM = 92.2
Standard Deviation (SD) = 2.53 BPM
95% Confidence Interval (CI) = [90.3, 94.1] BPM

The narrow confidence intervals indicate low variability across repeated tests and demonstrate the measurement precision of the system. The slightly higher variation in the child’s BPM is consistent with normal physiological fluctuations expected in paediatric patients.

3.2 System Robustness and Reproducibility across Conditions

To validate the reproducibility of the system, we conducted additional tests in varied physical states. Specifically, the adult participant was asked to perform light exercise (walking for 3 minutes), after which the BPM was recorded using the same system. The BPM increased to an average of 101.4 BPM, reflecting the expected physiological response to physical activity. The child participant was observed during a period of moderate excitement (after playing), and the system recorded an average BPM of 108.7 BPM, which still falls within the normal range for active children.

These results demonstrate that the system is capable of capturing changes in heart rate in real time and remains reliable under various physiological conditions beyond resting state. Although the current version is optimized for stationary measurements, these findings support its potential applicability for broader scenarios, such as fitness tracking or preliminary triage assessments in clinical settings.

4. Conclusions

The article presents a novel heart rate monitoring system that utilizes Arduino technology, specifically designed to be cost-effective and portable, making it accessible for individuals in low-resource settings. The system employs a fingertip sensor to accurately measure heart rate, with testing conducted on both a 40-year-old lecturer and a 2-year-old child, revealing average heart rates of 73.3 BPM and 92 BPM, respectively, which are within normal ranges for their age groups. Furthermore, the findings suggest that this heart rate monitoring system could be widely adopted in both clinical and personal health contexts, offering a reliable alternative to more expensive commercial devices. This work also discusses potential future enhancements to improve the system's functionality, underscoring the importance of developing accessible healthcare technologies that can effectively monitor vital signs and improve health outcomes in diverse populations.

References

[1] Suh, Myung-kyung, Chien-An Chen, Jonathan Woodbridge, Michael Kai Tu, Jung In Kim, Ani Nahapetian, Lorraine S. Evangelista, and Majid Sarrafzadeh. "A remote patient monitoring system for congestive heart failure." *Journal of medical systems* 35 (2011): 1165-1179. https://doi.org/10.1007/s10916-011-9733-y

[2] Santos, Marcus AG, Roberto Munoz, Rodrigo Olivares, Pedro P. Rebouças Filho, Javier Del Ser, and Victor Hugo C. de Albuquerque. "Online heart monitoring systems on the internet of health things environments: A survey, a reference model and an outlook." *Information Fusion* 53 (2020): 222-239. https://doi.org/10.1016/j.inffus.2019.06.004

[3] Li, Chao, Xiangpei Hu, and Lili Zhang. "The IoT-based heart disease monitoring system for pervasive healthcare service." *Procedia computer science* 112 (2017): 2328-2334. https://doi.org/10.1016/j.procs.2017.08.265

[4] Issac, Roshan, and M. S. Ajaynath. "CUEDETA: A real time heart monitoring system using android smartphone." In *2012 Annual IEEE India Conference (INDICON)*, pp. 047-052. IEEE, 2012. https://doi.org/10.1109/INDCON.2012.6420587

[5] Hussein, Ahmed Faeq, Marlon Burbano-Fernandez, Gustavo Ramírez-Gonzalez, Enas Abdulhay, and Victor Hugo C. De Albuquerque. "An automated remote cloud-based heart rate variability monitoring system." *IEEE access* 6 (2018): 77055-77064. https://doi.org/10.1109/ACCESS.2018.2831209

[6] Goldberg, Lee R., John D. Piette, Mary Norine Walsh, Theodore A. Frank, Brian E. Jaski, Andrew L. Smith, Raymond Rodriguez et al. "Randomized trial of a daily electronic home monitoring system in patients with advanced heart failure: the Weight Monitoring in Heart Failure (WHARF) trial." *American heart journal* 146, no. 4 (2003): 705-712. https://doi.org/10.1016/S0002-8703(03)00393-4

[7] Nancy, A. Angel, Dakshanamoorthy Ravindran, PM Durai Raj Vincent, Kathiravan Srinivasan, and Daniel Gutierrez Reina. "Iot-cloud-based smart healthcare monitoring system for heart disease prediction via deep learning." *Electronics* 11, no. 15 (2022): 2292. https://doi.org/10.3390/electronics11152292

[8] Nashif, Shadman, Md Rakib Raihan, Md Rasedul Islam, and Mohammad Hasan Imam. "Heart disease detection by using machine learning algorithms and a real-time cardiovascular health monitoring system." *World Journal of Engineering and Technology* 6, no. 4 (2018): 854-873. https://doi.org/10.4236/wjet.2018.64057

[9] Triantafyllidis, Andreas, Carmelo Velardo, Tracey Chantler, Syed Ahmar Shah, Chris Paton, Reza Khorshidi, Lionel Tarassenko, Kazem Rahimi, and SUPPORT-HF Investigators. "A personalised mobile-based home monitoring system for heart failure: The SUPPORT-HF Study." *International journal of medical informatics* 84, no. 10 (2015): 743-753. https://doi.org/10.1016/j.ijmedinf.2015.05.003

[10] Khan, Mohammad Ayoub, and Fahad Algarni. "A healthcare monitoring system for the diagnosis of heart disease in the IoMT cloud environment using MSSO-ANFIS." *IEEE access* 8 (2020): 122259-122269. https://doi.org/10.1109/ACCESS.2020.3006424

[11] Schönfelder, Martin, Georg Hinterseher, Philipp Peter, and Peter Spitzenpfeil. "Scientific comparison of different online heart rate monitoring systems." *International Journal of Telemedicine and Applications* 2011, no. 1 (2011): 631848. https://doi.org/10.1155/2011/631848

[12] Mack, David C., James T. Patrie, Paul M. Suratt, Robin A. Felder, and Majd Alwan. "Development and preliminary validation of heart rate and breathing rate detection using a passive, ballistocardiography-based sleep monitoring system." *IEEE Transactions on information technology in biomedicine* 13, no. 1 (2008): 111-120. https://doi.org/10.1109/TITB.2008.2007194

[13] Christ, Michael, Stefan Störk, Marcus Dörr, Hans J. Heppner, Christian Müller, Rolf Wachter, Uwe Riemer, and Trend HF Germany Project. "Heart failure epidemiology 2000–2013: insights from the German federal health monitoring system." *European journal of heart failure* 18, no. 8 (2016): 1009-1018. https://doi.org/10.1002/ejhf.567

[14] Adamson, Philip B., Anthony Magalski, Frieder Braunschweig, Michael Böhm, Dwight Reynolds, David Steinhaus, Allyson Luby et al. "Ongoing right ventricular hemodynamics in heart failure: clinical value of measurements derived from an implantable monitoring system." *Journal of the American College of Cardiology* 41, no. 4 (2003): 565-571. https://doi.org/10.1016/S0735-1097(02)02896-6

[15] Achten, Juul, and Asker E. Jeukendrup. "Heart rate monitoring: applications and limitations." *Sports medicine* 33 (2003): 517-538. https://doi.org/10.2165/00007256-200333070-00004

[16] Evans, Jarrett, Amy Papadopoulos, Christine Tsien Silvers, Neil Charness, Walter R. Boot, Loretta Schlachta-Fairchild, Cindy Crump, Michele Martinez, and Carrie Beth Ent. "Remote health monitoring for older adults and those with heart failure: adherence and system usability." *Telemedicine and e-Health*22, no. 6 (2016): 480-488. https://doi.org/10.1089/tmj.2015.0140

[17] Devoe, Lawrence, Steven Golde, Yevgeny Kilman, Debra Morton, Kimberly Shea, and Jennifer Waller. "A comparison of visual analyses of intrapartum fetal heart rate tracings according to the new national institute of child health and human development guidelines with computer analyses by an automated fetal heart rate monitoring system." *American journal of obstetrics and gynecology* 183, no. 2 (2000): 361-366. https://doi.org/10.1067/mob.2000.107665

[18] Sarmah, Simanta Shekhar. "An efficient IoT-based patient monitoring and heart disease prediction system using deep learning modified neural network." *Ieee access* 8 (2020): 135784-135797. https://doi.org/10.1109/ACCESS.2020.3007561

[19] Pecchia, Leandro, Paolo Melillo, and Marcello Bracale. "Remote health monitoring of heart failure with data mining via CART method on HRV features." *IEEE Transactions on Biomedical Engineering* 58, no. 3 (2010): 800-804. https://doi.org/10.1109/TBME.2010.2092776

[20] Raina, Amresh, William T. Abraham, Philip B. Adamson, Jordan Bauman, and Raymond L. Benza. "Limitations of right heart catheterization in the diagnosis and risk stratification of patients with pulmonary hypertension related to left heart disease: insights from a wireless pulmonary artery pressure monitoring system." *The Journal of heart and lung transplantation* 34, no. 3 (2015): 438-447. https://doi.org/10.1016/j.healun.2015.01.983

[21] Arulananth, T. S., and B. Shilpa. "Fingertip based heart beat monitoring system using embedded systems." In *2017 International conference of Electronics, Communication and Aerospace Technology (ICECA)*, vol. 2, pp. 227-230. IEEE, 2017. https://doi.org/10.1109/ICECA.2017.8212802

[22] Pawar, Prajakta A. "Heart rate monitoring system using IR base sensor & Arduino Uno." In *2014 Conference on IT in business, Industry and Government (CSIBIG)*, pp. 1-3. IEEE, 2014. https://doi.org/10.1109/CSIBIG.2014.7057005

[23] Aarthi, Yamuna, B. Karthikeyan, N. Prithivi Raj, and M. Ganesan. "Fingertip based estimation of heart rate using photoplethysmography." In *2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS)*, pp. 817-821. IEEE, 2019. https://doi.org/10.1109/ICACCS.2019.8728432

[24] Devis, Yesica, Yuda Irawan, Fransiskus Zoromi, and Mohd Rinaldi Amartha. "Monitoring system of heart rate, temperature and infusion in patients based on microcontroller (Arduino Uno)." In *Journal of Physics: Conference Series*, vol. 1845, no. 1, p. 012069. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1845/1/012069

[25] Sagar, R., and HV Ravish Aradhya. "Remote monitoring of heart rate and music to tune the heart rate." In *2015 Global Conference on Communication Technologies (GCCT)*, pp. 678-681. IEEE, 2015. https://doi.org/10.1109/GCCT.2015.7342748

[26] Mukherjee, Saikat, Arpita Ghosh, and Subir Kumar Sarkar. "Arduino based wireless heart-rate monitoring system with automatic SOS message and/or call facility using SIM900A GSM module." In *2019 International Conference on Vision Towards Emerging Trends in Communication and Networking (ViTECoN)*, pp. 1-5. IEEE, 2019. https://doi.org/10.1109/ViTECoN.2019.8899504