Tackling the Overlooked Problem: A Novel Approach for Healthcare Systems by IoT

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Abstract: This research paper addresses a significant literature gap in healthcare monitoring systems by proposing a novel methodology that integrates weight monitoring into an Internet of Things (IoT)-based framework. In the era of technological advancement, IoT serves as a powerful tool for obtaining health-related data remotely. While existing studies have explored various IoT applications, including connected cars and automated residences, the crucial parameter of patient weight has been overlooked in current healthcare monitoring systems. The proposed methodology leverages the ESP8266 module for Wi-Fi connectivity, facilitating seamless data transmission and remote monitoring capabilities. Key IoT applications such as oxygen sensors, heart rate sensors, ECG modules, and temperature sensors are already established in healthcare systems, but the incorporation of a weight sensor is essential for a holistic understanding of a patient's overall health. Regular monitoring of weight provides valuable insights, enabling healthcare providers to make informed decisions. Through the integration of a weight sensor, this research enhances the capabilities of healthcare providers, allowing them to remotely access accurate and real-time weight measurements alongside other vital signs. This comprehensive approach empowers healthcare professionals to deliver more effective care, especially in remote settings where regular patient visits may be challenging.

Keywords: Internet of Things (IoT), ESP8266, Health Kit, ECG module, MAX3010x.

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Nomenclature

Abbrivation	Expansion
IoT	Internet of Things
IoTA	Internet of Things Analytics
BLE	Bluetooth Low Energy
GSM	Global System for Mobile Communications
LCD	Liquid Crystal Display
ECG	ElectroCardioGram
BMI	Body Mass Index
CED	Chronic Energy Deficiency

1. Introduction

With the continual growth of innovations, professionals are consistently exploring cutting-edge electronic devices to simplify the detection of bodily anomalies. Technologies supporting the IoT enable the development of advanced, non-invasive healthcare systems. The IoT is a product of ongoing research in modern information and communications technology, offering the potential to enhance the quality of life for urban inhabitants. The design of cost-effective healthcare systems, capable of efficiently managing and providing a wide array of medical services while reducing overall costs, is increasingly crucial. This urgency arises due to the rapid growth of the world's population and the escalating prevalence of chronic diseases. Both patients and doctors stand to gain significantly from the integration of the IoT into the healthcare industry. This integration involves a network that spans systems, applications, and devices, enabling patients and doctors to monitor, track, and log vital data and medical information. Gadgets such as smart meters, wearable health bands, running shoes, RFID-based smartwatches, and smart video cameras contribute to this interconnected system [6]. Furthermore, smartphone apps play a key role in maintaining medical records, providing real-time alerts, and delivering emergency assistance. Consequently, while the overall cost of treatment may decrease, the quality of medical care and patient safety can both witness improvement. The IoT holds immense potential in the medical field, particularly in facilitating virtual consultations for remote medical treatment. However, the effective management of the vast amounts of data produced by these interconnected IoT devices poses a significant challenge for healthcare providers. Overcoming this challenge requires the implementation of IoTA techniques, employing methods like data extraction and analytics to transform raw data into valuable, pertinent information for medical purposes.

The rest of the paper is organized as follows: Section II covers the needs and advantages of the IoT-based health kit, Section III explains the Literature review, Section IV mentions the research gap, Section V explains the components needed for the health kid, Section VI details the methodology and result, Section VII concludes the paper with the future scope.

2. Need for IOT-based Health Kit

The need for IoT-based health kits stems from the growing demand for personalized and proactive healthcare. These kits provide individuals with the ability to monitor and manage their health in real-time, regardless of their location. With the integration of sensors, wearable devices, and connectivity, IoT-based health kits enable the collection and transmission of health data to healthcare professionals. This empowers individuals to take control of their health, promotes early detection of potential health issues, facilitates remote patient monitoring, and allows for timely interventions. Furthermore, in areas with limited healthcare infrastructure, IoT-based health kits bridge the gap by providing accessible and cost-effective healthcare solutions. In urban areas, where access to healthcare facilities may be more readily available, IoT-based health kits provide convenience and efficiency. Patients can monitor their vital signs, such as heart rate, blood pressure, and glucose levels, in real-time from the comfort of their homes. The kits enable remote monitoring, allowing healthcare professionals to receive data and provide timely interventions, reducing the need for frequent hospital visits. On the other hand, in rural areas where healthcare resources are often limited, IoT-based health kits play a crucial role in bridging the gap. These kits can be easily deployed in remote locations, enabling individuals to monitor their health conditions without traveling long distances. The data collected can be transmitted to healthcare professionals in urban centers, facilitating timely diagnosis and interventions. IoT-based health kits empower individuals in rural areas to take control of their health and improve overall healthcare accessibility [1].

The main advantages of the IoT in the health kid are explained in Table 1.

Table 1. *Advantages of IoT-based health kits*

Advantage	Explanation
Remote monitoring	Enables real-time monitoring of vital signs and health conditions from anywhere, reducing the need for frequent hospital visits.
Timely interventions	Allow healthcare professionals to receive data promptly, enabling timely interventions and reducing the risk of complications.
Enhanced accessibility	Bridges the gap between urban and rural healthcare by providing remote monitoring capabilities to individuals in remote areas.
Enhanced accessibility	Enables individuals to actively participate in their healthcare, promoting self-management and prevention.
Cost-effectiveness	Reduces healthcare costs by minimizing hospital visits, especially for patients with chronic conditions.

3. Literature Review

In this section of our paper, we have explored different approaches for designing an IoT-based AI Health Kit. The research has emphasized that there are multiple options to construct the model, utilizing various sensors such as the Pulse Rate Sensor, Heartbeat Sensor, ECG module, and more. Different microcontrollers, including Arduino, ESP32, and Raspberry Pi, can be employed, each with its own set of advantages and limitations, which must be considered during the system design process. Furthermore, the choice of microcontroller also influences the programming language utilized for developing the prototype. For instance, Arduino employs C/C++ as its programming language, NodeMCU uses Lua as its scripting language, and Raspberry Pi supports Python, C, and Java programming languages.

In 2020, Alfin Hidayat et al., [2] implemented a design for an IoT-based Independent Pulse Oximetry Kit as an early detection tool for COVID-19 symptoms. In their research, they utilized the ESPDUINO-32 module and the NodeMCU module. The system operates by using the ESPDUINO-32 as a receiver or BLE receiver, which is connected to a Pulse Oximetry BLE sensor. The ESPDUINO-32 and NEO-6M GPS are serially connected to a NodeMCU, enabling real-time monitoring of data sent to server databases. Fingerprints are used as patient identification within this tool. The Pulse Oximetry Kit, based on the Internet of Things, is designed using a Pulse Oximetry BLE sensor that adheres to existing health standards. The Pulse Oximetry BLE sensor is connected to the ESPDUINO-32 via integrated Bluetooth. Once the data is received by the ESPDUINO-32, it is sent to the NodeMCU serially [2]. The NodeMCU then transmits the received data to the Database Server over a Wi-Fi network. Their research can be concluded:

i) The Pulse Oximetry Kit based on the Internet of Things employs a Pulse Oximetry BLE sensor to measure the dissolved O2 levels in the blood.
ii) The data is processed by the ESPDUINO-32 and transmitted to the Database Server by the NodeMCU.The research and trial stage involved determining the minimum threshold for dissolved O2 levels in the blood.

In 2020, Lavanya et al., [3], implemented a model for remote health monitoring that utilizes the Raspberry Pi 3 Model B, a credit card-sized minicomputer or system on a chip. In addition to the microcontroller, they have integrated a heartbeat sensor, blood pressure sensor, temperature sensor, gas sensor, and LED display into the device. The LED display shows the readings from the different sensors. Through their research, they have concluded that their health monitoring system, designed using Raspberry Pi, offers an alternative to regular and expensive clinic checkups. It allows individuals to monitor their health conditions frequently from the comfort of their homes, including temperature, heartbeat, blood pressure, and respiration values. The system can also send SMS notifications to doctors or relatives. This automatic system creates a more comfortable environment for patients. In the future, they plan to develop a mobile app that can store data from all sensors and devices. The app will efficiently send notifications about the current status of the patient and enable data storage in the cloud. Additionally, they aim to include phone video calls or phone call services to inform doctors, medical helpers, and family members about the patient's situation. This will also provide the patient with a means to communicate with them [3].

In 2020, Uzzal Kumar Prodhan et al., [4] presented a groundbreaking study addressing healthcare challenges in rural Bangladesh. Through an advanced telemedicine model, they successfully implemented a low-cost primary healthcare service, utilizing a web portal, app, Raspberry Pi, and sensors for data collection. This innovative solution overcomes geographical barriers, providing crucial medical support to remote populations. The integration of affordable hardware enables real-time monitoring and accurate diagnosis, while the web-based dashboard enhances healthcare delivery. The research's significance extends globally, serving as a blueprint for regions with limited healthcare infrastructure. By empowering individuals to overcome medical barriers, this study showcases the transformative potential of technology in bridging healthcare gaps [4].

In 2020, Antim Dev Mishra et al., [5] implemented an IoT-based health monitoring system that showcases a comprehensive and commendable effort in utilizing emerging technologies to enhance healthcare delivery. The integration of multiple sensors, real-time data display, cloud connectivity, and an emergency alert system demonstrates the potential for efficient and patient-centric healthcare solutions. The paper highlights the benefits of a holistic approach to healthcare by incorporating various health parameters into a single system, allowing for a comprehensive view of the patient's health status. Additionally, the ability to securely store and transfer data to the cloud facilitates remote collaboration between patients and healthcare professionals. The consideration of power optimization and the inclusion of an emergency alert mechanism further enhance the system's practicality and patient safety. However, the research paper would benefit from providing more technical details, conducting a comprehensive evaluation, and addressing scalability and cost considerations. Nonetheless, the study contributes to the field of IoT in healthcare and paves the way for further advancements in remote patient monitoring and treatment [5].

In 2023, L. Srinivasan et al., [12] presented a system designed to assist individuals with paralysis in communicating their needs and monitoring their health status. The system utilizes motion tracking and GSM technology to enable patients to transmit messages through specific movements of any movable body part. The proposed system addresses the challenges faced by paralyzed individuals who are unable to communicate effectively due to impaired motor coordination. By allowing patients to display text messages on an LCD screen or send SMS messages via GSM, the system provides a means for them to interact with healthcare professionals, therapists, and loved ones remotely. Additionally, the system incorporates continuous monitoring of vital signs, such as heart rate, using photoplethysmography and transmits the data wirelessly to a receiver device. This allows healthcare providers to monitor multiple patients simultaneously and receive alerts in case of any anomalies or changes in a patient's condition. Overall, the system offers paralyzed individuals a means of achieving physical autonomy and enhancing their quality of life through communication and health monitoring capabilities. The study's findings demonstrate the potential of this technology to positively impact the lives of those affected by paralysis [12].

In 2020, Rasheedha et al., [13] presented an Arduino-based automated dosage prescription system using a load cell for anesthesia in medical applications. Currently, anesthesiologists often rely on manual procedures, which involve complex calculations for dosage determination. This manual process poses a risk of medication errors, especially in critical care and anesthesia. The project's goal is to address this issue by creating an automated dosage prescription system. This system calculates the dosage based on the patient's weight and height, obtained through a weight sensor or load cell. The HX711 ADC acts as an interface, converting analog signals to digital for the microcontroller. The resulting dosage level is displayed on a monitor. This automated system aims to enhance precision, mitigate medication errors, and provide a safer approach to anesthesia administration in patient care [13].

In 2021, Alinea Dwi Elisanti et al., [14] designed a research project focused on the prototype design of a BMI measurement system for adolescents, aiming to prevent CED in pregnancy. CED during pregnancy is linked to inadequate nutrition during adolescence, particularly in young women. The prevention of CED in adolescent girls involves BMI screening and nutritional education. Unfortunately, BMI measurement in adolescents is infrequently conducted due to time constraints in health services, which are primarily tailored for toddlers. To address this gap, an anthropometric tool was designed as a BMI measurement prototype. The intention is to develop this prototype into an Android application, streamlining the BMI screening process with reduced measurement errors. This innovation is particularly valuable in the context of time-limited health services, providing health workers, adolescents, and women in Indonesia with a practical and independent means of BMI measurement [14].

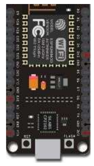
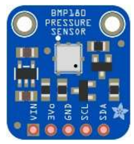
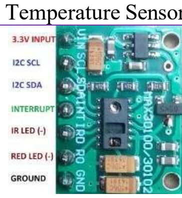
4. Literature Gap

The existing literature in the field of healthcare monitoring systems has primarily focused on various sensors such as oxygen sensors, heart rate sensors, ECG modules, and temperature sensors. These sensors play a crucial role in monitoring the vital signs of patients and transmitting the data to healthcare providers. In addition, some studies have successfully incorporated web/app-based interfaces to facilitate communication between patients and doctors, enabling remote monitoring and consultations. However, one significant parameter that has been largely overlooked in these studies is the patient's weight. Monitoring a patient's weight is an essential aspect of healthcare, as it can provide valuable insights into their overall health and help doctors make informed decisions. Unfortunately, most existing papers in the literature review have not utilized any sensors to measure the patient's weight. Consequently, in the remote monitoring system, doctors often need access to this crucial piece of information. To address this drawback, our proposed methodology includes the integration of a weight sensor into the healthcare monitoring system. By incorporating this sensor, we aim to bridge the gap in the literature and provide healthcare providers with accurate and real-time weight measurements of the patients. This information can be seamlessly transmitted through the web/app-based interface, allowing doctors to remotely access and analyze the weight data along with other vital signs. Our proposed methodology aims to rectify this gap by introducing a weight sensor into the system, enabling comprehensive remote monitoring and enhancing the capabilities of healthcare providers to deliver effective care.

5. Components

The suggested health kit includes a variety of IoT components that perform critical operations within the device. These components (Table 2) are required for the kit to perform properly and effectively. Each component contributes to various elements of health monitoring, data collecting, and communication, ensuring that consumers receive full and reliable information. The table below highlights the role in the device's development [7].

Table 2. *Component and its role in IoT-based health kits*

Components	Role
 ESP8266 (WiFi-Module)	ESP8266 plays a crucial role in developing an IoT-based health kit by providing Wi-Fi connectivity, enabling data transmission, and remote monitoring capabilities.
 ECG Module	The ECG module in an IoT-based health kit measures and analyses the heart's electrical activity, enabling monitoring, detection of abnormalities, and diagnosis of cardiac conditions through the generation of ECG waveforms.
 Temperature Sensor	The temperature sensor in an IoT-based health kit enables accurate measurement and monitoring of body temperature, facilitating the detection of fever or changes in temperature for early illness detection and health monitoring.
 Oxygen Sensor	The MAX3010x series sensors, such as MAX30102 and MAX30105, enable non-invasive measurement of blood oxygen saturation (SpO2) levels using infrared and red LEDs, aiding in real-time monitoring and early detection of respiratory issues in IoT-based health kits.
 Weight Sensor	The weight sensor, or load cell, in an IoT-based health kit, enables accurate measurement and monitoring of weight, facilitating tracking of weight changes, fitness goals, and personalized health monitoring.
 18650 Li-ion Battery	The I8650 Li-ion Battery is used to provide power to the circuit.
 Jumper Wire	Jumper Wires are used to establish wired communication between sensors and the ESP8266 module.

6. Methodology and Results

This section presents the methodology adopted for addressing the literature gap in healthcare monitoring systems by integrating a weight sensor into an IoT-based framework. The research methodology encompasses various stages, including a comprehensive literature review, system design, weight sensor integration, data acquisition and processing, data transmission and remote monitoring, web-based interface development, testing, evaluation, and results (Fig. 2). By following this systematic approach, the research aims to enhance the capabilities of healthcare providers in remote monitoring and enable accurate and real-time weight measurements, along with other vital signs, for improved patient care. The figure below shows a prototype with oxygen sensors, heart rate sensors, ECG modules, a weight measurement device, and temperature sensors (Fig. 1).

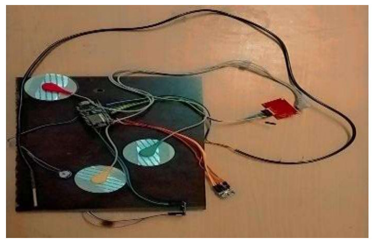


Fig. 1. *Prototype Photo*

The code of the prototype is designed in such a way as the implementation of an ESP8266-based healthcare monitoring system. Additionally, it includes functionality for reading and plotting ECG data. The setup function initializes the ESP8266 module, establishes a connection to a Wi-Fi network, starts the Web server on port 80, and sets up routes for different sensor readings. It also initializes the serial communication for debugging purposes. The setup function initializes the ESP8266 module, establishes a connection to a Wi-Fi network, starts the web server on port 80, and sets up routes for different sensor readings. It also initializes the serial communication for debugging purposes. In the loop function, the server handles incoming client requests. It then reads the sensor data using corresponding functions and stores the readings in the respective variables. The ECG data is read and updated in the ECG data array, with ecgIndex keeping track of the current position. The handleOxygen(), handleTemperature(), handleHeartRate(), handleWeight(), and handleECG() functions are request handlers for their respective routes. When a client requests a specific sensor reading, these functions send the corresponding sensor reading as a response in plain text format (HTTP status 200).

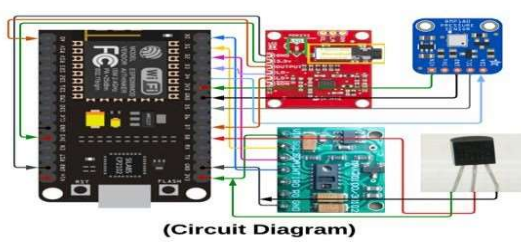


Fig. 2. *ESP8266 interfacing with Heart Rate, Temperature, ECG, and Oxygen Sensors.*

The read_Oxygen, read_Temperature, read_HeartRate, read_Weight, and read_ECG Sensor functions simulate sensor readings by reading analog or digital pins. In the provided code, the values are obtained directly from specific pins, but they should be replaced with actual code to interface with the corresponding sensors. To make this code a complete healthcare monitoring system, it needs to integrate an actual weight sensor and implement data processing, storage, and analysis. The integrated weight measurement device in the system is capable of accurately measuring up to 80 kg [9]. The weight reading obtained from the device is transmitted to the ESP8266, which then sends the data to the doctor for further analysis and monitoring (Fig. 3).

The results of the proposed model are depicted in Fig. 4. The readings are collected through the sensors shown in Figures 2 and 3. The collected data can be viewed using the web-based application, which displays readings for blood pressure, oxygen level, weight, and other parameters.

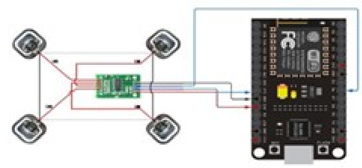


Fig. 3. *ESP8266 interfacing Weight-measurement Sensor.*

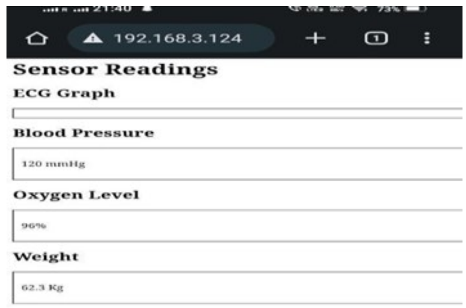


Fig. 4. *Sensor Readings on Web-portal*

Due to the size of the ECG module's graph, it is not visible on the portal. To obtain the output, COM12 has been utilized [8]. This ensures the availability of a larger display or an appropriate interface to view the ECG graph. The result is shown in Fig. 5.

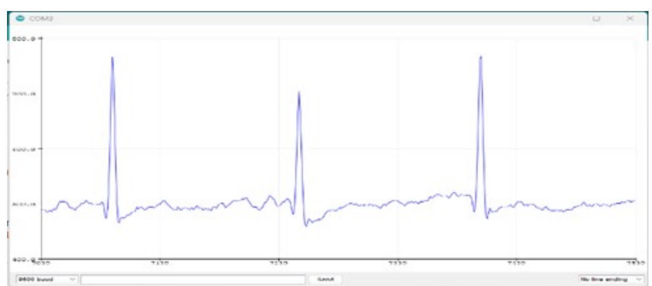


Fig. 5. *ECG Reading*

7. Conclusion

This research study has concentrated on the development of an IoT-based AI Health Kit for remote healthcare monitoring. Through the assessment of the literature, we discovered a vacuum in the body of knowledge about the monitoring of patient weight in healthcare monitoring systems. Our suggested technique adds a weight sensor to the IoT-based AI Health Kit to close this gap and provide precise and immediate weight assessments. The future scope of this research paper includes validation studies, advanced data processing methods, the integration of additional sensors, real-time alerting and decision support systems, cloud-based storage and analytics, long-term monitoring and remote patient management, privacy and security considerations, as well as an assessment of cost-effectiveness and scalability.

8. Future Scope

The future scope of our research paper includes several areas of exploration and development in the field of healthcare monitoring systems. Enhanced data processing and analysis techniques, such as using machine learning and artificial intelligence, can be explored to extract valuable insights from sensor data, enabling more accurate diagnoses and proactive healthcare interventions. Integration of additional sensors, like those for blood pressure, glucose levels, and respiratory rate, can provide a more comprehensive view of a patient's health status, enhancing the effectiveness of the monitoring system [11]. Real-time alerting and decision support systems are important for timely intervention and improved patient care. Developing mechanisms to notify healthcare providers or caregivers based on abnormal readings and incorporating decision support systems can enhance the quality of care provided. Cloud-based storage and analytics platforms can offer scalable and secure data management, enabling remote patient monitoring and collaborative care. Privacy and security concerns must be addressed to protect patient data [10]. Expanding research to enable long-term monitoring and remote patient management can involve developing mobile applications or wearable devices for patients to monitor their health parameters and transmit data to healthcare providers. Validation studies and clinical trials in real-world settings can evaluate the system's performance and impact on patient outcomes. Considering cost-effectiveness and scalability is crucial, including assessing sensor costs, maintenance requirements, and scalability potential for deployment in various healthcare settings. By exploring these areas, our research can contribute to the advancement of healthcare monitoring systems, leading to improved patient outcomes and enhanced healthcare delivery.

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