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An Integrated Approach Using IoT and CNN

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Abstract**—** This page explores the use of IoT in the healthcare sector, focusing on the Internet of Medical Things (IoMT). IoT applications in healthcare can improve care quality, reduce stress for medical professionals, and enhance patient monitoring and treatment. The study also discusses the factors influencing patient health and the structure of Cellular Neural Networks (CNN). The research then presents a combined CNN model with IoT for patient healthcare, using a variety of sensors to monitor patient health and environmental conditions. The collected data is processed using the CNN algorithm to identify potential health risks. The system also includes a remote monitoring system, abnormal alerts, and patient health status prediction. The model has shown promising results in improving healthcare services by enabling early detection and timely treatment of health issues. The study concludes that the combined CNN model with IoT has great potential in the healthcare sector.

Keywords**—** CNN, IoMT, IoT, ESP32, SpO2

I. INTRODUCTION

A. Internet of Medical Things

In the healthcare sector, IoT plays a very important role. IoT has great potential in the healthcare industry, also known as IoMT (Internet of Medical Things) [6]. The applications of IoT include improving the quality of healthcare, reducing stress for medical professionals, remote and real-time patient health monitoring systems to improve tracking and treatment, patients can control their health at home without having to go to the hospital. The application of IoT technology in healthcare plays a role in helping healthcare centers operate efficiently and patients get better treatment. Some benefits of IoT are Real- time monitoring and reporting, Cost reduction, Data classification and analysis, Tracking and alerting, Remote medical support, etc.

B. Factors related to patient health

Human health is influenced by a variety of factors, including natural (physical, chemical), biological, economic, social, and ecological factors. Changes in the environment, especially the social environment, can have negative impacts on the psychology, emotions, and health of individuals, leading to various diseases. Professional care from doctors and family is an indispensable factor that helps patients overcome illness. Below are the measures for patient healthcare.

C. Structure of the standard Cellular Neural Network

The Cellular Neural Network [1,3,4,8] has a structure similar to the Hopfield network but is interconnected to form a grid (a two-dimensional array or matrix). It is an array of parallel processors, the principle diagram of a neural cell C(i, j) is based on the electrical circuit model as shown in fig 1.

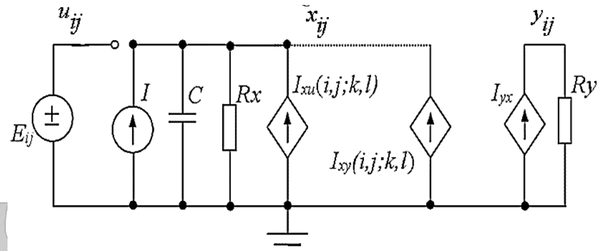

Fig 1. Principle of CNN electrical circuit

In which u_{ij}, x_{ij}, y_{ij} are respectively the input signals, state, and output of the neural (i,j) (or the (i,j) cell). The x_{ij} state is normalized with a value in the range $0 \leq x_{ij} \leq 1$. The input voltage u_{ij} is assumed to be a constant with a value in the range [0;1]. Each cell $C(i,j)$ contains a voltage source E_{ij},, a current source I, a capacitor C, a resistor R_x in the state circuit and R_y in the output circuit. Then $I_{xu}(i,j;k,l)$ and $I_{xy}(i,j;k,l)$ are the input current sources and output current sources, the current is controlled by linear voltage at the output circuit, defined as follows:

$$I_{xu}(i,j;k,l) = B(i,j;k,l)' \, u_{kl}$$
$$I_{xy}(i,j;k,l) = A(i,j;k,l)' \, y_{kl} \qquad (1)$$

According to the diagram (Figure 1), $u_{ij}=E_{kl}$, where E_{kl} is a direct current source (a constant). To calculate the conductivity of the circuit, denoted as G (Siemen) (the reciprocal of resistance R), we follow the electrical circuit formula:

$$G=\frac{I_{xu}(i,j;k,l)}{u_{kl}}=\frac{1}{R_u}=\frac{1}{\Omega}=B(i,j;k,l) \quad (2)$$

Thus, $B(i,j;k,l)$ represents the conductivity of the electrical circuit we have:

$$I_{xy}(i,j;k,l)=A(i,j;k,l)y_{kl} \quad (3)$$

$$A(i,j;k,l)=\frac{I_{xy}(i,j;k,l)}{y_{kl}}=\frac{1}{R_y}=\frac{1}{\Omega}=G \quad (4)$$

$$I_{yx}=\frac{1}{2R_y}\left(|x_{ij}+1|-|x_{ij}-1|\right)=\frac{1}{R_y}\left[\frac{1}{2}\left(\begin{matrix}|x_{ij}+1|- \\ |x_{ij}-1|\end{matrix}\right)\right]=\frac{1}{R_y}f(x_{ij}) \quad (5)$$

với mọi $C(k,l) \in N_r(i,j)$.

Each nonlinear element (each neuron cell) is a source of current $I_{xy}=\frac{1}{R_y}f(x_{ij})$ controlled by voltage defined by $f(x_{ij})$. The coefficients A(i,j;k,l) and B(i,j;k,l) are referred to as feedback sample coefficients and control sample coefficients respectively. In CNN [8] the number of elements of the cell created by the external feedback array ngoài $A(i,j;k,l)$ là $(2r+1)^2$, internal feedback $\left(-\frac{1}{R}\right)$, the control array $B(i,j;k,l)$ is $(2r+1)^2$ elements, and an additional threshold I.

II. COMBINED CNN MODEL WITH IoT

A. Objective definition

Applying the knowledge about IoT theory, neural network [2], cellular neural network, and health care measures for An Integrated Approach Using IoT and CNN will use IoT devices including sensors [5]: Non-contact infrared temperature sensor MLX90614; MAX30102 heart rate and blood oxygen sensor; SW1801 vibration/tilt sensor module; Sound sensor; DHT11 temperature and humidity sensor.

The MAX30102 heart rate and blood oxygen sensor; SW1801 vibration/tilt sensor module; Sound sensor; DHT11 temperature and humidity sensor are suitable sensors in the field of health care, playing a role in monitoring and supervising the patient's health status.

The data from these sensors will be collected and calculated based on the CNN algorithm [4] used in the embedded program for ESP32 to determine the current status when measuring the blood oxygen concentration and heart rate of the patient, thereby helping to identify the cause and provide a solution when a risk occurs.

B. Features of IoT devices in use

1. Module IoT ESP32

Module ESP32 [7] is a popular wireless module for developing IoT applications, it is a microcontroller capable of Wi-Fi and Bluetooth connectivity. ESP32 provides a powerful platform for developing IoT projects such as controlling applications like lights, fans, and integrating smart sensors, connecting to the cloud, and many other wireless applications. ESP32 features GPIO, UART, SPI, I2C, and RF broadcasting technology.

Operating principle

The operating principle of ESP32 involves combining a microcontroller and wireless connectivity modules. ESP32 uses a main processor with high processing speed and memory to run source code and perform functions such as control, data processing, and communication.

Integrated Wi-Fi and Bluetooth modules in ESP32 allow the device to connect to Wi-Fi networks and other Bluetooth devices. This allows ESP32 to send and receive wireless data, participate in smart networks, and interact with other devices and applications via wireless connectivity.

In addition, ESP32 also has GPIO, UART, SPI, I2C pins for connecting and communicating with other components and sensors. This makes ESP32 a flexible platform for developing IoT applications and similar projects.

Applications

Smart home: ESP32 can be used to build a smart home system. It can connect with devices such as temperature sensors, lights, smart plugs, and control them via Wi-Fi or Bluetooth.

Environmental monitoring: ESP32 can be used to collect data from environmental sensors such as temperature, humidity, air quality, and light sensors. The data is sent to a server or mobile application for monitoring and analysis.

Remote tracking and control: ESP32 can be used to track and control devices remotely. For example, it can be used to control lighting systems, irrigation systems, or security systems remotely via a mobile application.

Robot control: ESP32 can be used as a controller for robots. It can connect with motor modules, sensors, and cameras to control and collect data from the robot.

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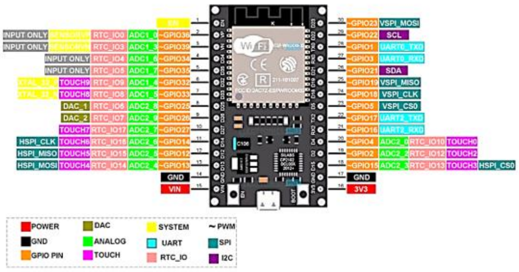

Fig 2. *Module IoT ESP32*

2. Temperature Sensor MLX90614

The GY-906 MLX90614 is a non-contact temperature sensor based on IR that can measure the

Fig 3. *Temperature Sensor MLX90614*

temperature of an object within a range from -70 ° C to +382.2° C and the ambient temperature from - 40 ° C to 125° C without needing physical contact with the object whose temperature needs to be measured. It integrates an I2C connection port for temperature reading communication with controllers.

3. Oxygen Sensor MAX30102

The sensor MAX30102 is designed to accurately and continuously measure heart rate and blood oxygen levels (SpO2). It uses optical technology to track small changes in blood through the fingertip or wrist, helping to detect early cardiovascular and respiratory problems.

Fig 4. *Sensor MAX30102*

4. Vibration/Tilt Sensor SW1801

The SW1801 sensor is a compact module used to detect vibrations and changes in tilt angle. In healthcare applications, it can be used to monitor the abnormal movements of patients, such as falls or convulsions, helping to provide timely alerts to medical staff.

Fig 5. *Vibration/Tilt Sensor SW1801*

5. Sound Sensor

The sound sensor is capable of detecting and measuring the intensity of surrounding sounds. In a healthcare environment, it can be used to monitor coughing, snoring, or other sounds emitted by patients, providing useful data for diagnosing and monitoring respiratory or sleep issues.

Figure 6. *Sound Sensor*

6. Temperature and Humidity Sensor DHT11

The sensor DHT11 is a popular module for measuring environmental temperature and humidity. Monitoring the temperature and humidity in patient rooms or special care areas is crucial to ensure an ideal living environment for patients, while also assisting in the prevention of diseases related to environmental conditions.

Fig 7. *Temperature and Humidity Sensor DHT11*

C. Listing of Features

1. Remote Monitoring System

The remote monitoring system integrates sensors that continuously measure strong vibrations and tilt angles to monitor abnormal movements such as falls or seizures of the patient. The sound sensor will measure sounds like coughing and snoring or other related sounds, helping to monitor the patient's respiratory status and sleep. The sensor DHT11 will monitor the ambient temperature in the room or special care areas. The MAX30102 heart rate and blood oxygen sensor monitor and measure the patient's heart rate, SpO2 in real-time. The non-contact infrared temperature sensor MLX90614 will measure the patient's body temperature.

2. Abnormal Alerts

When the system performs monitoring, data on the patient's health status will be continuously updated. The patient's health indicators will be compared with the safety threshold to alert abnormalities, including: Detecting body temperature signs of being too low or too high, sending abnormal notifications; Detecting and alerting when heart rate or SpO2 exceeds the safety threshold, sending notifications to avoid bad situations; Alerting falls or strong movements to prevent serious injuries; Monitoring sounds and sending notifications when detecting abnormal sounds assists in diagnosing respiratory problems or emergency situations; Sending notifications when the ambient temperature exceeds the safety threshold (too high or too low) to ensure the optimal environment for the patient's health.

3. Predicting the patient's health status

The system uses the Cellular Neural Network model combined with IoT for the patient healthcare problem, it will be able to predict, to give the current status of the patient, the causes of the symptoms that the patient encounters. Health factors have a relationship that affects each other, having the nature of a cellular neural network, interacting between cells. From those influences, we can determine the causes as well as predict the patient's health status.

4. Designing a CNN Model combined IoT for the patient healthcare

The cellular neural network model combined with IoT for the patient healthcare problem includes sensor devices read by the microcontroller via the internet sent to Blynk and can use the website or phone to monitor.

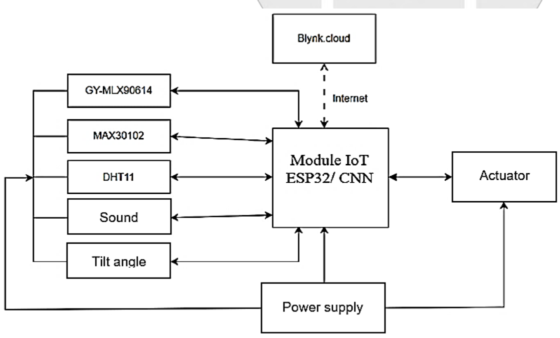

Fig 8. *Block Diagram of the System*

The patient health care support monitoring system is illustrated in Fig 8. The system comprises a power supply block for the microcontroller (ESP32/CNN), sensors, and actuators. The central processing block is responsible for reading sensor input values such as the non-contact infrared temperature sensor MLX90614; Heart rate and blood oxygen sensor MAX30102; Vibration/Tilt Sensor Module SW1801; Sound sensor;

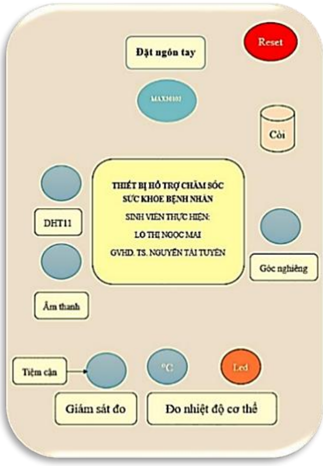

Fig 9. *Design of a health care support device model*

Temperature and humidity sensor DHT11. The CNN microcontroller is connected to the internet to transmit data to Blynk to monitor health parameters. The actuator block is the block that carries out actions decided by the central processing block. Fig 9 represents a demo model of a patient healthcare device. The model is equipped with sensors to monitor health parameters and environmental temperature that affect health, it is simple to use and suitable for all ages, the measured data is sent to the cloud, allowing doctors and relatives to monitor the health status of the elderly and patients. The sensors DHT, sound sensors, and tilt angle sensors will operate to collect information next to the patient. The sensor MAX30102 will measure heart rate and blood oxygen concentration when a finger is placed on it; At the same time, when the hand is placed down, the device will approach the proximity sensor at a distance of 1-2 cm, it will detect and activate the measuring device, the infrared temperature sensor will measure body temperature. All health indicators measured by the device are monitored through Blynk's open application.

5. Selecting the control app platform - Blynk app

Blynk provides a mobile app and API that allows users to connect and control IoT devices using sensors and input signals. The user interface is flexibly customizable to control IoT devices in a customized way and create complex actions and interactions through code. The Blynk app supports hardware platforms, including Arduino, Raspberry Pi, ESP8266, ESP32, and many more. This allows users to easily integrate IoT devices into their projects without needing much programming experience.

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Fig 10. *Blynk monitor measures body temperature*

III. EXPERIMENTAL RESULTS

A. Program Algorithm

1. Main Program

- Start
- Initialize
- Run setup() function
- Run loop() function
  - Read data from sensors
  - Check conditions of the data
  - The conditions and send notifications to Blynk
  - Send sensor data to Blynk and Google Sheet
  - Wait for a certain period of time
- Repeat the loop() function
- End

2. CNN Program for module ESP32

- Initialize the CNN network with 81 cells, each corresponding to a measurement
- Set the weight coefficients for each cell based on the relationship between measurements
- Update the CNN network based on the current state of the central cell and neighboring cells.
- Repeat the update process.
- Use the output state of the cells to extract values from the measurements
- End

B. Experimental Results

Through the research, design, and implementation process, the study has achieved the following results: To complete the model, we had to connect the sensors with ESP32 for preliminary testing. Below is the initial circuit board necessary for serving the model:

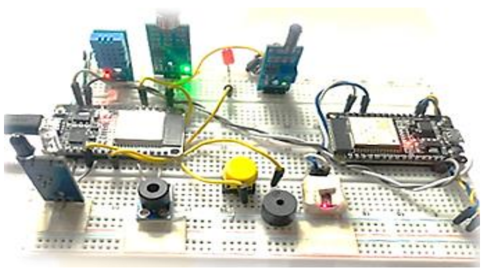


Fig 11. *The circuit board containing the sensors*

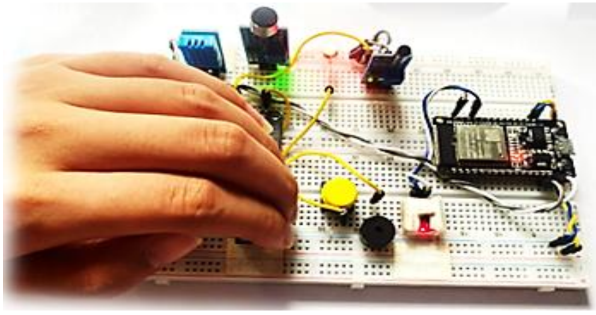


Fig 12. *Testing the circuit board with various sensors*

Fig 13. *Model of health care support equipment*

Images of health-related values collected through sensors:

```
17:55:16.061 -> Heart rate: 34.78 bpm
17:55:16.061 -> SpO2: 0.00 %
17:55:16.061 -> Temperature: 32.30 °C
17:55:16.061 -> Sound Level: 4095
17:55:16.061 -> Motion Detected: 4095
17:55:16.772 -> Beat Detected!
17:55:17.025 -> Beat Detected!
17:55:17.616 -> Beat Detected!
17:55:17.843 -> Beat Detected!
17:55:18.155 -> Heart rate: 153.89 bpm
17:55:18.155 -> SpO2: 94.00 %
17:55:18.155 -> Temperature: 32.30 °C
17:55:18.155 -> Sound Level: 4095
17:55:18.155 -> Motion Detected: 4095
```

Fig 14. *The serial monitor displaying the values*

```
17:35:43.960 -> Nhiệt độ phòng: 29.40 °C
17:35:43.960 -> Độ ẩm: 76.80 %
17:35:43.960 -> Âm thanh: 4095
17:35:43.960 -> Vận động: 256
17:35:45.950 -> Nhiệt độ cơ thể: 35.55 °C
17:35:45.950 -> Nhiệt độ phòng: 29.40 °C
17:35:45.950 -> Độ ẩm: 76.80 %
17:35:45.950 -> Âm thanh: 4095
17:35:45.950 -> Vận động: 80
17:35:47.970 -> Nhiệt độ cơ thể: 35.63 °C
17:35:47.970 -> Nhiệt độ phòng: 29.40 °C
17:35:47.970 -> Độ ẩm: 76.80 %
17:35:47.970 -> Âm thanh: 4095
17:35:47.970 -> Vận động: 37
17:35:49.937 -> Nhiệt độ cơ thể: 35.53 °C
17:35:49.937 -> Nhiệt độ phòng: 29.40 °C
17:35:49.937 -> Độ ẩm: 76.80 %
17:35:49.977 -> Âm thanh: 4095
17:35:49.977 -> Vận động: 345
```

Fig 15. *Serial monitor containing sensor values*

Experimental image of running health values on Blynk, through multiple trials, the results achieved were stable:

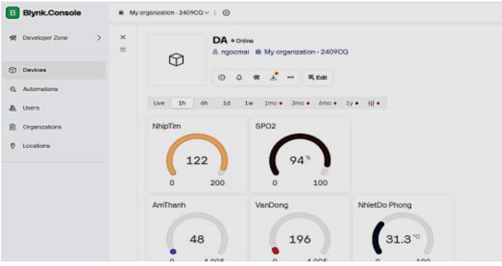


Fig 16. *The Heart rate and SpO2 measurement results*

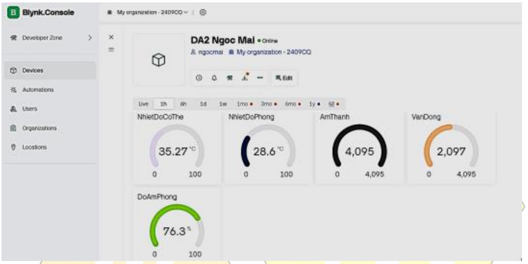


Fig 17. *Blynk screen for body temperature measurement*

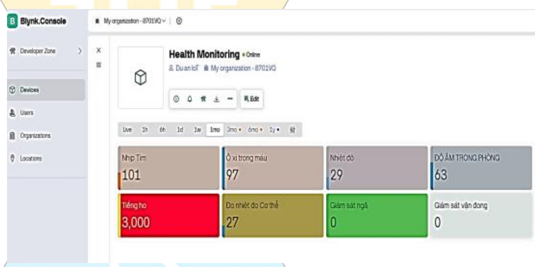
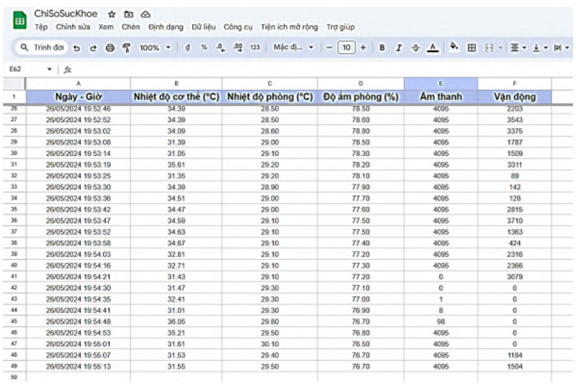


Fig 18. *Blynk screen with sensors*

Below is the image of data pushed to Google Sheet (Fig 19). The values of sensors collected from ESP32 will be pushed to Google Sheet for storage and health index tracking, contributing significantly to the research and analysis of disease causes. The data includes the date and time of measurement, body temperature, room temperature - humidity, sound, patient's activity index.



ChiSoSucKhoe

	Ngày - Giờ	Nhiệt độ cơ thể (°C)	Nhiệt độ phòng (°C)	Độ ẩm phòng (%)	Âm thanh	Vận động
26	26/05/2024 19:52:46	34.39	28.50	78.50	4095	2203
27	26/05/2024 19:52:52	34.39	28.50	78.60	4095	3543
28	26/05/2024 19:53:02	34.09	28.60	78.80	4095	3375
29	26/05/2024 19:53:08	31.39	29.00	78.50	4095	1787
30	26/05/2024 19:53:14	31.05	29.10	78.30	4095	1509
31	26/05/2024 19:53:19	35.61	29.20	78.20	4095	3311
32	26/05/2024 19:53:25	31.35	29.20	78.10	4095	89
33	26/05/2024 19:53:30	34.39	28.90	77.90	4095	142
34	26/05/2024 19:53:36	34.51	29.00	77.70	4095	128
35	26/05/2024 19:53:42	34.47	29.00	77.60	4095	2815
36	26/05/2024 19:53:47	34.59	29.10	77.50	4095	3710
37	26/05/2024 19:53:52	34.63	29.10	77.50	4095	1363
38	26/05/2024 19:53:58	34.67	29.10	77.40	4095	424
39	26/05/2024 19:54:03	32.81	29.10	77.20	4095	2316
40	26/05/2024 19:54:16	32.71	29.10	77.30	4095	2366
41	26/05/2024 19:54:21	31.43	29.10	77.20	0	3079
42	26/05/2024 19:54:30	31.47	29.30	77.10	0	0
43	26/05/2024 19:54:35	32.41	29.30	77.00	1	0
44	26/05/2024 19:54:41	31.01	29.30	76.90	8	0
45	26/05/2024 19:54:48	36.05	29.80	76.70	98	0
46	26/05/2024 19:54:53	35.21	29.50	76.80	4095	0
47	26/05/2024 19:55:01	31.61	30.10	76.50	4095	0
48	26/05/2024 19:55:07	31.53	29.40	76.70	4095	1184
49	26/05/2024 19:55:13	31.55	29.50	76.70	4095	1504

Fig 19. *Image of data pushed to Google Sheet*

C. Evaluation of test results

The experimental results of Integrated Approach Using IoT and CNN have been tested to provide a smart healthcare and monitoring system. Through the model testing process, the results achieved are quite good, the health values collected from IoT devices are relatively accurate to reality. The cellular neural network model has helped the system become effective and reliable, helping to predict the current condition of the patient such as increased blood pressure, body temperature outside the allowable range, blood oxygen concentration, snoring. Data is sent to the Cloud for storage and sent to the smartphone for family doctors and relatives.

IV. CONCLUSION

The patient health care support system model has been fully operational, and can monitor health on a phone application or on a personal computer. The sensors collect health information, then send it to Blynk and store it in Google Sheets with the purpose of providing health-related warnings, thereby being able to warn early about the risk of related diseases, helping to detect early and treat promptly. In the context of the increasing demand for advanced and effective health care solutions. The author team has researched Integrated Approach Using IoT and CNN application for post accounting patient healthcare, which has proven its feasibility and great potential in improving the quality of health care services. Through detailed testing and analysis, the project has achieved many encouraging results, contributing significantly to improving the effectiveness of patient health monitoring and care.

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