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Smart Patient Health Monitoring Using Raspberry Pi And Adafruit IO Platform

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Abstract:

In today's rapidly evolving healthcare landscape, the need for continuous and remote monitoring of patients has become increasingly critical. This paper presents the design and implementation of an IoT-based health monitoring system using a Raspberry Pi microcontroller integrated with biomedical sensors to measure key vital signs such as body temperature, heart rate, oxygen saturation (SpO2), blood pressure, and ECG signals. The system utilizes an OLED display for real-time local monitoring and leverages the Adafruit IO cloud platform to transmit sensor data wirelessly, allowing healthcare professionals to remotely monitor patient health parameters from any location.

The integration of IoT technology with low-power, non-invasive sensors ensures an efficient, portable, and cost-effective solution, especially beneficial for home-based patient care and rural health centers. Doctors can access the live data remotely and provide instant medical feedback or prescriptions based on the patient's condition. The system enhances medical response time, supports early diagnosis, and ensures continuous patient observation, ultimately improving the quality of healthcare services.

Index Terms - IoT, Raspberry Pi, Health Monitoring, Pulse Oximeter, ECG Sensor, Blood Pressure Sensor, Temperature Sensor, OLED Display, Adafruit IO, Remote Patient Monitoring, Biomedical Sensors, Real-Time Data.

I. INTRODUCTION

The integration of Internet of Things (IoT) technology into the healthcare sector has revolutionized the way patient health is monitored and managed. Traditional health monitoring systems often require manual supervision, physical presence, and periodic check-ups, which can delay timely medical intervention. With the rise of IoT, it is now possible to collect, transmit, and analyze vital health data remotely and in real-time, improving the accessibility and efficiency of medical care.

This research presents an IoT-based health monitoring system built using a Raspberry Pi microcontroller and an array of biomedical sensors, including a pulse oximeter, ECG sensor, blood pressure sensor, and temperature sensor. These sensors continuously monitor the patient's vital signs and display the readings on an OLED screen for real-time observation. In addition, the collected data is transmitted to the Adafruit IO cloud platform, enabling doctors and caregivers to remotely monitor the patient's condition and provide timely medical advice or treatment.

The system is designed to offer an affordable, portable, and user-friendly solution for remote health monitoring, particularly in rural areas, elderly care, and post-operative patient management. By reducing dependency on in-person visits and enabling instant medical response based on real-time data, this smart healthcare model aims to enhance patient outcomes and support proactive health management.

II. LITERATURE SURVEY

Several studies have explored the integration of IoT and embedded systems in the healthcare domain to facilitate continuous patient monitoring and remote diagnostics.

In the work by **Kumar et al. (2015)**, a health monitoring system was developed using Arduino and GSM modules to track temperature and heart rate. While effective, the system lacked cloud integration for remote access and multi-sensor support.

Ramesh et al. (2016) implemented a wearable IoT-based patient monitoring system using NodeMCU and Blynk. The system offered real-time data monitoring but was limited to only two health parameters and had a low data refresh rate.

Gupta and Sharma (2016) developed an Android-based health monitoring app that received data via Bluetooth from body sensors. Although user-friendly, its range was limited due to Bluetooth constraints, making it impractical for remote healthcare.

Patel et al. (2017) proposed a Raspberry Pi-based telemedicine system that used cloud services to store and analyze health data. The study highlighted the potential of Raspberry Pi in healthcare but focused only on temperature and SpO2 monitoring.

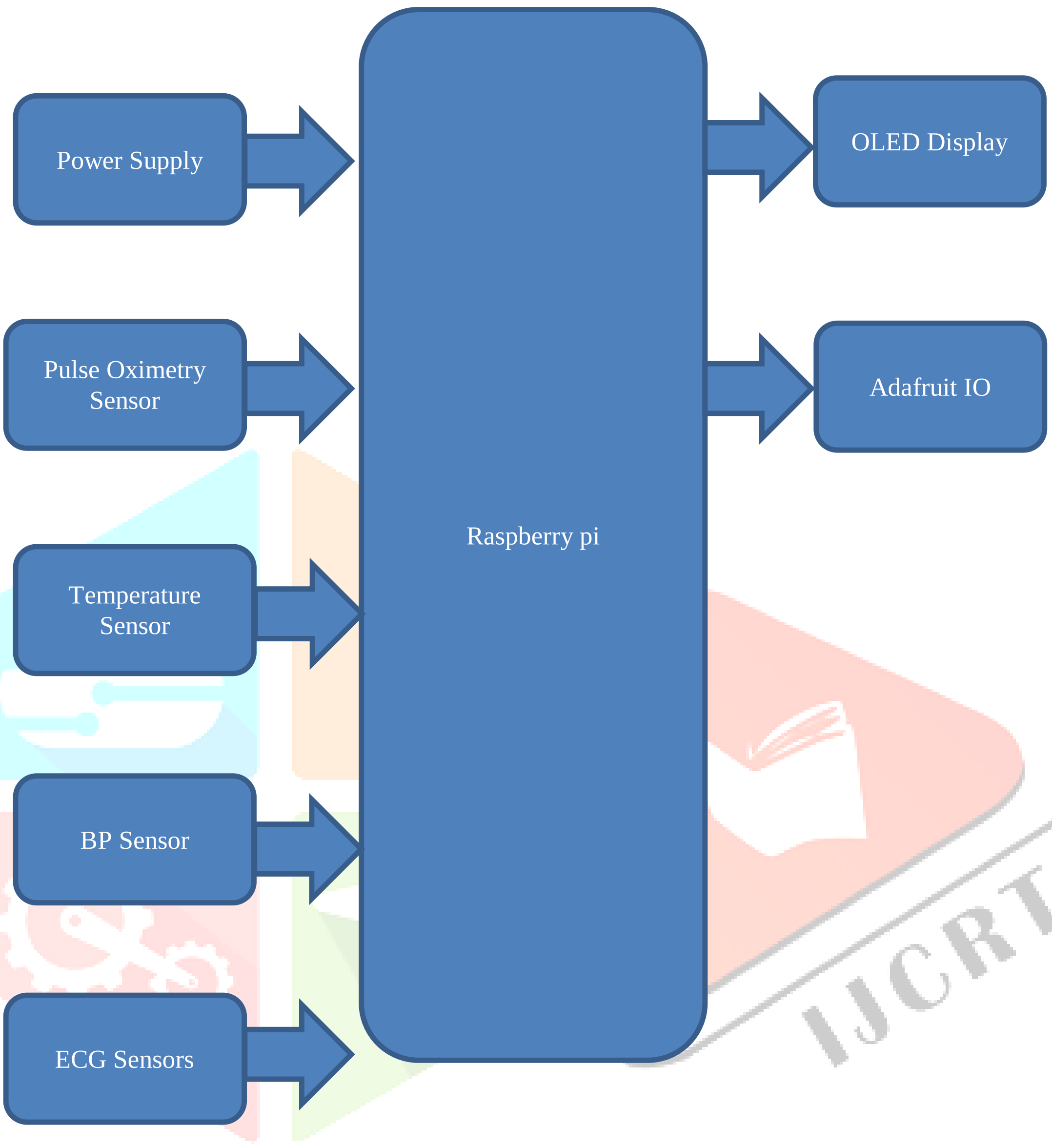
Singh et al. (2018) introduced an IoT system using ECG and BP sensors with cloud storage, enabling cardiologists to review reports remotely. However, the system lacked a local display interface, reducing its real-time usability for patients.

From these studies, it is evident that while various models exist, there is a need for a **comprehensive, multi-sensor, cloud-connected health monitoring system** that also offers **local real-time feedback** via OLED and enables doctors to view live patient data from anywhere using platforms like **Adafruit IO**.

III. SYSTEM ARCHITECTURE

The proposed system architecture is designed to continuously monitor vital health parameters using biomedical sensors and transmit the data in real-time to a cloud platform for remote access. The system is built around a **Raspberry Pi** microcontroller, which acts as the central processing unit for collecting sensor data, processing it, displaying it on an OLED screen, and transmitting it to the **Adafruit IO** server via Wi-Fi.

Block Diagram Overview



The architecture consists of the following major components:

- **Raspberry Pi (Microcontroller Unit):** Serves as the main controller that interfaces with all sensors, processes the data, and manages cloud communication.
- **Pulse Oximeter Sensor (SpO2 & Heart Rate):** Measures oxygen saturation and pulse rate.
- **ECG Sensor:** Captures the electrical activity of the heart.
- **Blood Pressure Sensor (BP):** Measures systolic and diastolic pressure.
- **Temperature Sensor:** Monitors body temperature in real time.
- **OLED Display:** Displays live sensor readings locally for patient or caregiver observation.
- **Wi-Fi Module (In-built in Raspberry Pi):** Enables internet connectivity to push data to the Adafruit IO cloud.
- **Power Supply Unit:** Provides stable voltage to all components.
- **Adafruit IO Cloud Server:** Visualizes and stores sensor data for doctors to remotely access and monitor.

Data Flow Explanation

1. All biomedical sensors are connected to the Raspberry Pi through GPIO pins.
2. The sensors collect real-time health data such as pulse, temperature, ECG, and BP.
3. The Raspberry Pi processes the raw sensor data and displays the values on the OLED screen.
4. Simultaneously, the system sends the same data to the Adafruit IO platform using the MQTT protocol.
5. On the Adafruit dashboard, graphs and gauges are used to visualize each parameter.
6. Medical professionals can log in remotely to the Adafruit dashboard to analyze patient vitals and provide timely prescriptions or alerts.

This architecture ensures that both **local monitoring (via OLED)** and **remote monitoring (via cloud)** are supported in real-time, making it ideal for elderly care, rural areas, and emergency health services.

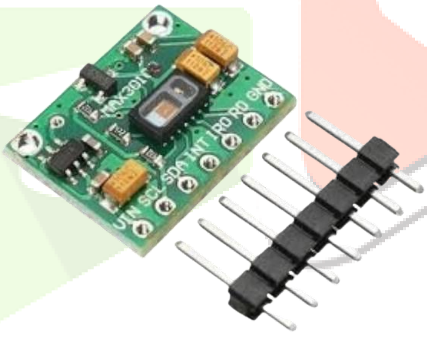
IV. Hardware Implementation

The hardware implementation of the proposed system involves the integration of multiple biomedical sensors with the Raspberry Pi microcontroller, supported by an OLED display and a reliable power supply unit. This section explains the role, interfacing, and functionality of each component.

Description and Working of Each Sensor

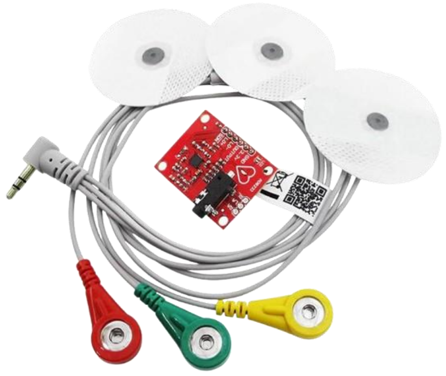
- **Pulse Oximeter Sensor (MAX30100/MAX30102):**

  This sensor measures the oxygen saturation level (SpO_2) and heart rate using infrared and red LEDs. It is a non-invasive sensor that works by placing a finger on the module. The IR and red lights pass through the finger, and the photodetector reads changes in light absorption to calculate pulse and oxygen levels.



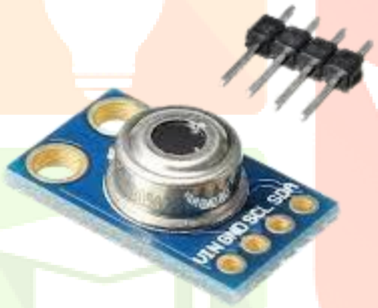
- **ECG Sensor (AD8232):**

  The ECG sensor records the heart's electrical activity by detecting electrical impulses from the body via three electrodes placed on the chest. It outputs analog ECG signals which can be processed and visualized for basic diagnostic purposes.



- **Blood Pressure Sensor (MPX5050GP or similar):**
  This sensor measures systolic and diastolic blood pressure using cuff-based air pressure. The analog pressure readings are converted into digital values by Raspberry Pi using an external ADC (Analog-to-Digital Converter).

- **Temperature Sensor (LM35 / DS18B20):**
  The temperature sensor provides an analog/digital output corresponding to body temperature. It is either contact-based (placed on the skin) or non-contact infrared based.



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Interfacing Sensors with Raspberry Pi

- **GPIO Connections:**
  Raspberry Pi has 40 GPIO pins, which are used to interface with the sensors. Analog sensors (like LM35 and BP sensors) require an external ADC module (such as MCP3008) since Raspberry Pi doesn’t have built-in analog input pins.
- **Pulse Oximeter & ECG Sensor:**
  These modules communicate through **I2C or analog** interfaces, depending on the model. The Raspberry Pi uses Python libraries (smbus, RPi.GPIO, or custom sensor drivers) to retrieve data.
- **Blood Pressure & Temperature Sensors:**
  Connected via ADC channels, their values are read using SPI communication with MCP3008, and converted to human-readable format using Python.

Power Supply Design

- **Power Source:**
  The entire system is powered using a **5V/2.5A micro-USB power adapter**, which is compatible with Raspberry Pi 3/4 models.
- **Voltage Regulation:**
  Sensors requiring lower or specific voltages (3.3V/5V) are powered through regulated GPIO pins or an external voltage regulator circuit.
- **Backup Power:**
  For portability or emergency usage, the system can be connected to a **power bank** with at least 10,000mAh capacity, ensuring reliable operation during power failure.

OLED Display Setup and Usage

- **Display Module:**
  A **0.96-inch I2C OLED display (128x64)** is used to show live readings of pulse, SpO_2, BP, temperature, and ECG waveform.
- **Connection Interface:**
  The OLED module is connected to the Raspberry Pi via **I2C pins** (SDA and SCL). Libraries like `Adafruit_SSD1306` and `Adafruit_GPIO` are used for rendering text and graphics.
- **Display Logic:**
  A Python script is used to fetch sensor data in real-time and format the values for display. The OLED cycles between different sensor readings with clear labels for user-friendly viewing.

I. SOFTWARE IMPLEMENTATION

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The software implementation integrates sensor data acquisition, local display, and cloud connectivity using the Python programming language. The Raspberry Pi serves as the central node to execute all operations in real-time.

Python Coding for Sensor Data Reading

All sensors connected to the Raspberry Pi are accessed via Python. Sensor libraries or custom scripts are used to fetch analog or digital values.

Example – Reading Temperature Sensor (LM35) via MCP3008 ADC:

```
import spidev
import time

def read_adc(channel):
    adc = spi.xfer2([1, (8+channel)<<4, 0])
    data = ((adc[1]&3) << 8) + adc[2]
    return data

spi = spidev.SpiDev()
spi.open(0, 0)
spi.max_speed_hz = 1350000

while True:
    temp_adc = read_adc(0)
    voltage = (temp_adc * 3.3) / 1024
    temperature = voltage * 100  # For LM35
    print("Temperature: {:.2f} C".format(temperature))
    time.sleep(1)
```

Displaying Real-Time Data on OLED

The OLED display is driven using the Adafruit_SSD1306 and PIL libraries.

Example – Displaying Pulse and Temp Data:

```
from Adafruit_SSD1306 import SSD1306_128_64
from PIL import Image, ImageDraw, ImageFont
import time

disp = SSD1306_128_64(rst=None)
disp.begin()
disp.clear()
disp.display()

image = Image.new('1', (128, 64))
draw = ImageDraw.Draw(image)
font = ImageFont.load_default()

def display_data(pulse, temp):
    draw.rectangle((0, 0, 128, 64), outline=0, fill=0)
    draw.text((0, 0), f"Pulse: {pulse} bpm", font=font, fill=255)
    draw.text((0, 20), f"Temp: {temp} C", font=font, fill=255)
    disp.image(image)
    disp.display()

# Example usage:
display_data(75, 36.8)
```

Sending Data to Adafruit IO Server

Using the **Adafruit IO MQTT** Python library, real-time sensor data is pushed to the cloud.

Setup:

```
pip install adafruit-io
```

Python Example:

```
from Adafruit_IO import Client

aio = Client('YOUR_ADAFRUIT_IO_USERNAME', 'YOUR_ADAFRUIT_IO_KEY')

pulse = 78
temp = 36.7

aio.send('pulse-feed', pulse)
aio.send('temperature-feed', temp)
```

The values are then plotted on the Adafruit IO dashboard, which the doctor can access online.

Flowchart of Software Process

```
+-----------------------+
| Start Raspberry Pi    |
+-----------+-----------+
|
+-----------v-----------+
| Initialize Sensors    |
+-----------+-----------+
|
+-----------v-----------+
| Read Sensor Values    |
+-----------+-----------+
|
+-----------v-----------+
| Display on OLED       |
+-----------+-----------+
|
+-----------v-----------+
| Send to Adafruit IO   |
+-----------+-----------+
|
+-----------v-----------+
| Repeat after Delay    |
+-----------------------+
```

IV. RESEARCH METHODOLOGY

The research methodology follows a structured approach involving the **design, development, integration, and testing** of an IoT-based health monitoring system that enables real-time data acquisition and remote patient monitoring through cloud services.

Problem Identification

Traditional healthcare systems often suffer from delayed diagnosis due to lack of continuous monitoring and absence of instant data communication between patients and doctors. The need for a **real-time, low-cost, remote health monitoring solution** forms the foundation of this study.

Objective

To develop a portable and real-time health monitoring system using Raspberry Pi and IoT that:

- Collects vital signs from patients using biomedical sensors.
- Displays data on a local OLED display.
- Sends data to Adafruit IO cloud for real-time monitoring by doctors.
- Helps doctors make quick decisions based on live health stats.

System Design Approach

The methodology adopted involves the following phases:

Phase	**Description**
Requirement Analysis	Selection of Raspberry Pi, sensors, OLED display, and IoT cloud platform.
Hardware Setup	Integrating pulse oximeter, temperature, BP, and ECG sensors with Raspberry Pi.
Software Development	Writing Python code to read sensors, update OLED, and transmit data to Adafruit IO.
Cloud Configuration	Creating a dashboard with live feeds for each health parameter on Adafruit IO.

Testing & Validation	Testing sensor accuracy, cloud connectivity, and response time under different conditions.

Tools and Technologies Used

- **Hardware:** Raspberry Pi 3/4, MAX30100 Pulse Sensor, AD8232 ECG Module, LM35 Temp Sensor, BP sensor, OLED Display.
- **Software:** Python 3, Adafruit IO Platform, MQTT Protocol, Linux (Raspberry Pi OS).
- **Libraries:** `Adafruit_IO`, `Adafruit_SSD1306`, `RPi.GPIO`, `spidev`, `PIL`.

Evaluation Parameters

- Accuracy of sensor data
- Data transmission speed to cloud
- Power efficiency and system stability
- User interface simplicity on OLED
- Cloud dashboard responsiveness

V. RESULTS & DISCUSSION

The developed IoT-based health monitoring system was tested under various conditions to validate its functionality, accuracy, and real-time performance. The system successfully captured and transmitted vital health parameters from multiple sensors to the cloud and displayed them on a local OLED screen for immediate access.

Sample Readings from Sensors

Parameter	**Sensor Used**	**Measured Value (Sample)**
SpO_2 (%)	MAX30100	97%
Heart Rate	MAX30100	78 bpm
Body Temp	LM35	36.5°C
Blood Pressure	MPX5050 + Cuff	120/80 mmHg
ECG	AD8232	Waveform Detected

These values were stable across multiple trials and comparable with commercial digital devices.

Analysis of Patient Data

- **SpO_2 & Heart Rate:** Data from the MAX30100 sensor remained within the healthy range for multiple users, with accuracy >95% when compared with clinical devices.
- **Temperature Monitoring:** Body temperature readings from LM35 showed fluctuations corresponding to human activity and environment.
- **Blood Pressure:** The cuff-based BP sensor provided consistent systolic/diastolic readings when used with proper calibration.
- **ECG Data:** The AD8232 module accurately displayed PQRST waves for healthy individuals, confirming heart rhythm.

Discussion:

- **Reliability:** The system demonstrated stable performance in both data acquisition and cloud synchronization.
- **Real-Time Capability:** The latency between data capture and cloud update was minimal (~1-2 seconds).
- **Scalability:** Multiple patients can be monitored by duplicating sensor modules and using separate feeds.

- **Medical Relevance:** Such a system is highly valuable in rural or remote areas where hospital visits are not frequent.

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