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# IoT-BASED SYSTEM FOR CARDIOVASCULAR DISEASE MONITORING

***Arzigul Kimizbaeva, Bekjonov Shohruh***

*Tashkent State Technical University named after Islam Karimov, Tashkent, Uzbekistan*

Cardiovascular diseases remain among the leading causes of mortality worldwide. According to the World Health Organization (WHO), millions of people die each year from heart attacks, strokes, and other cardiovascular conditions. A major challenge in combating these diseases lies in their often asymptomatic early stages, which can delay diagnosis and reduce treatment effectiveness. Therefore, continuous and real-time monitoring of a patient's physiological parameters is crucial for the prevention and early detection of cardiovascular disorders.

In recent years, Internet of Things (IoT) technologies have found extensive application in healthcare. Through IoT devices, it is possible to remotely and automatically monitor key health indicators such as heart rate, blood pressure, oxygen saturation, and other vital signs. This approach enhances communication between patients and healthcare providers, improves diagnostic accuracy, and enables timely medical intervention in emergency situations.

IoT-based cardiovascular disease monitoring systems operate through several interconnected technological stages. In the first stage, sensors attached to the patient's body or integrated into wearable devices continuously measure physiological parameters such as heart rate, blood pressure, electrocardiogram (ECG) signals, blood oxygen saturation ($SpO_2$), and body temperature. These sensors typically transmit the collected data via wireless modules (e.g., Bluetooth Low Energy or Wi-Fi) to a data aggregator such as a smartphone, smartwatch, or dedicated gateway.

In the second stage, the collected data undergoes initial processing, which may include signal filtering, noise reduction, and feature extraction. For more

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complex analysis, the data is sent to a cloud server, where artificial intelligence or machine learning algorithms perform in-depth diagnostics.

In the third stage, the analyzed results are communicated back to the healthcare provider or the patient. If the system detects significant changes in heart rhythm, sudden spikes in blood pressure, or drops in oxygen saturation, it automatically sends an alert notification. This enables timely medical intervention before the condition worsens.

Thus, IoT-based cardiovascular monitoring systems provide continuous real-time observation, accurate diagnostics, and rapid response capabilities.

IoT-based cardiovascular disease monitoring systems can be categorized according to their measurement principles, data transmission methods, and level of analytical capability. One of the most common categories is wearable devices, which include smartwatches, fitness trackers, or specialized sensors with ECG capabilities. These devices measure heart rate, cardiac rhythm, and physical activity levels, enabling general assessment of cardiovascular health.

Another significant category is adhesive medical patches, which are attached to the patient's skin to continuously monitor ECG signals, blood pressure, or respiratory rate. Their advantage lies in the ability to perform long-term monitoring without interrupting daily activities.

Implantable devices are also an important direction in IoT technology for cardiovascular care. Examples include pacemakers and implantable loop recorders, which continuously record heart activity and transmit the data remotely to healthcare providers.

In addition, there are stationary monitoring systems, typically installed in hospitals or cardiology centers, designed for intensive observation of patients. These systems can monitor multiple patients simultaneously and usually consist of high-precision professional medical equipment.

IoT-based cardiovascular disease monitoring systems offer several notable advantages over traditional healthcare monitoring methods. Foremost among these is the ability to track a patient's health status in real time. This is particularly

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important for promptly identifying conditions such as changes in heart rhythm, sudden spikes in blood pressure, or decreases in oxygen saturation levels.

These systems provide continuous monitoring, allowing for the detection of subtle early signs of disease. This capability facilitates early diagnosis and the initiation of timely treatment measures. Furthermore, patients can be monitored from their homes without the need for frequent hospital visits, thereby reducing both time and financial costs.

Another key advantage of IoT-based systems is their ability to collect and analyze large volumes of data. Artificial intelligence algorithms can be employed in this process to assess disease risk, track treatment effectiveness, and deliver personalized recommendations. Additionally, these systems improve communication between patients and healthcare providers, thereby enhancing the overall efficiency of the healthcare system.

To demonstrate the practical aspects of IoT-based cardiovascular monitoring systems, we present a simple working example. This prototype measures heart rate and blood oxygen saturation ($SpO_2$) in real time, transmits the data wirelessly to a cloud server, and allows healthcare providers to view the readings remotely.

The primary sensing component in this setup is the Pulse Sensor or the MAX30102 optical heart rate and $SpO_2$ sensor. The sensor is connected to a microcontroller, such as the ESP32, which offers built-in Wi-Fi connectivity for direct internet access. The measured data undergoes initial filtering and normalization on the microcontroller, and is then transmitted to a cloud database via MQTT or HTTP protocol.

The collected data is visualized on a web application or mobile app. If the system detects sudden changes in heart rate or a dangerous drop in $SpO_2$ levels, it automatically sends an alert (push notification or SMS). This model can be scaled from small-scale clinical monitoring setups to large hospital networks.

Sample code (ESP32 + MAX30102 + ThingSpeak):

```
#include <WiFi.h>
#include "MAX30105.h"
```

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```
#include "heartRate.h"
#include "ThingSpeak.h"
const char* ssid = "WIFI_NAME";
const char* password = "WIFI_PASSWORD";
WiFiClient client;
unsigned long myChannelNumber = YOUR_CHANNEL_NUMBER;
const char * myWriteAPIKey = "YOUR_API_KEY";
MAX30105 particleSensor;
void setup() {
  Serial.begin(115200);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  ThingSpeak.begin(client);
    if (!particleSensor.begin(Wire, I2C_SPEED_STANDARD)) {
    Serial.println("Sensor not found!");
    while (1);
  }
  particleSensor.setup();
}
void loop() {
  long irValue = particleSensor.getIR();
  int bpm = 0;
    if (checkForBeat(irValue)) {
    bpm = getBPM();
    Serial.print("Heart Rate: ");
    Serial.println(bpm);
  }
```

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```
  ThingSpeak.setField(1, bpm);
 ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
 delay(20000);
}
```

IoT-based cardiovascular monitoring systems are widely applied in modern medical practice. They serve not only for disease detection but also for tracking treatment progress and effectively monitoring patients during the rehabilitation phase. For instance, in patients with chronic heart failure, such systems continuously track parameters like heart rate, blood pressure, and fluid balance, transmitting real-time data to healthcare providers.

In hospital settings, IoT systems are deployed in intensive care units to monitor patients' vital signs 24/7. This is particularly crucial in the postoperative period or in cases involving severe cardiovascular conditions. Additionally, portable home-based monitoring devices enable patients to self-track their health, receive medical recommendations, and obtain instant alerts in emergency situations.

Moreover, when integrated with telemedicine platforms, IoT systems facilitate efficient remote consultations between patients and doctors. This approach is especially beneficial for individuals living in remote areas or those unable to frequently visit healthcare facilities.

IoT-based cardiovascular monitoring systems are expected to evolve further and find broader applications in healthcare in the near future. One major direction of development is deeper integration with artificial intelligence and machine learning algorithms, enabling early prediction of cardiovascular diseases, identification of risk factors, and creation of personalized treatment plans.

Another anticipated trend is the widespread adoption of smart clothing and wearable medical sensors. For example, T-shirts or wristbands capable of continuously tracking heart activity would allow patients to monitor their health without wearing additional devices. Furthermore, the use of energy-harvesting technologies will make it possible to develop battery-free, energy-efficient sensors, which is an important step towards sustainability.

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Additionally, IoT monitoring systems connected to global healthcare networks will play a vital role in large-scale health crises, such as pandemics. Remote monitoring capabilities will speed up the flow of information between healthcare providers and patients, improving the overall efficiency of healthcare systems worldwide.

IoT-based cardiovascular disease monitoring systems are emerging as a crucial tool in enhancing the efficiency of diagnosis, prevention, and treatment in modern healthcare. Their ability to collect continuous real-time data, enable remote monitoring, and integrate with artificial intelligence makes them highly valuable for the early detection and treatment of heart diseases. In the future, these technologies are expected to become more compact, energy-efficient, and user-friendly, ultimately becoming an integral part of healthcare systems.

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