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Integrated low-cost wearable electrocardiograph system of primary assessment for cases of rural residents.

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Abstract

In recent years, advances in both technology and medicine have made great progress. With the development of technology, low-cost and high-precision sensors have emerged and microcontrollers with high computing power and low power consumption have been created. In densely populated urban areas, health care is provided by a set of hospitals and medical centers where every patient can find an immediate response to his health problem. However, medical care, particularly in non-urban areas, remains limited as many such areas do not have a hospital or medical center nearby. This results in inadequate medical care, both diagnostic and preventive, for the inhabitants of these areas. Today, the development of microprocessors, the high-speed internet and the low-cost sensors that have been developed can enable the creation of autonomous, accessible health monitoring units. In this work, an integrated low-cost, wearable electrocardiograph system is presented. The system is able to operate anywhere there is an active internet connection. The proposed system consists of two parts. Firstly, the wearable ECG which can be located in the patient's home. Secondly, the information system, in which the data is collected and visualized, so that the doctor has immediate access. Health is a precious commodity and the application of technology is imperative, especially for the health care of citizens in remote areas.

Introduction

Cardiovascular disease (CVD) is the leading cause of death globally, accounting for 32% of all deaths in 2019, with heart attack and stroke responsible for 85% of these. CVD is also the cause of 38% of premature deaths from non-communicable diseases. Many CVD cases can be prevented by managing risk factors like smoking, poor diet, and lack of exercise. Over 75% of CVD deaths occur in low- and middle-income countries. Early detection and treatment, including the use of electrocardiography (ECG), are crucial for managing CVD. Atrial fibrillation, the most common arrhythmia, is linked to serious cardiovascular events like heart failure and stroke and is best diagnosed with ECG, which records the heart's electrical activity. This paper presents an affordable ECG monitoring system, comprising a wearable device and an information system. The device, powered by a microcontroller and ECG sensor, transmits data wirelessly and can be used in remote health centers or homes. The system collects and visualizes ECG data, and digital signal filtering ensures reliable readings. Doctors can remotely access a patient's ECG, enhancing healthcare delivery.

Materials and Methods

Figure 1 depicts a reasonably typical ECG signal.

The P-R interval is the time from the beginning of the P wave to the start of the QRS com-plex. The QRS interval or duration or width, is the time from the beginning to the end of the QRS complex. The QT interval is the time from the beginning of the QRS complex to the end of the T wave. The RR interval is the time from the peak of one R wave to that of the following R wave

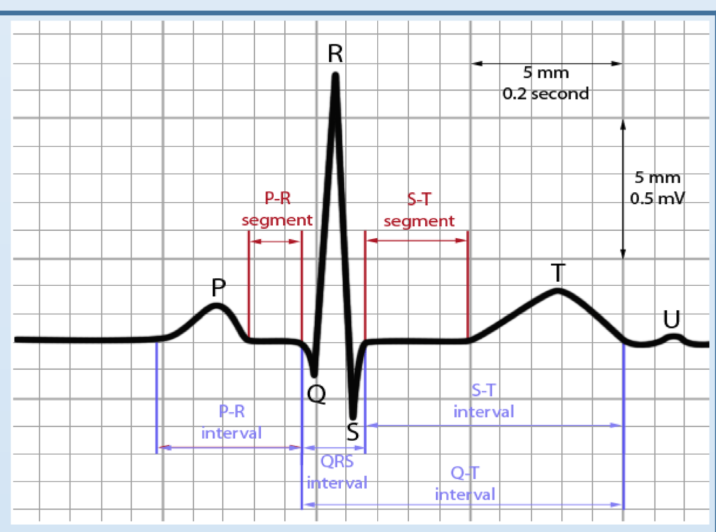

Fig. 1. Typical ECG signal

This study presents the implementation of a low-cost portable ECG monitoring station. The data transmission is done via a wireless network (Wi-Fi). Each station consists of a microcontroller and an ECG sensor. The microcontroller chosen is the affordable TTGO@ESP32 (Figure 2). The affordable and low power AD8232 was chosen as the ECG sensor (Figure 3).

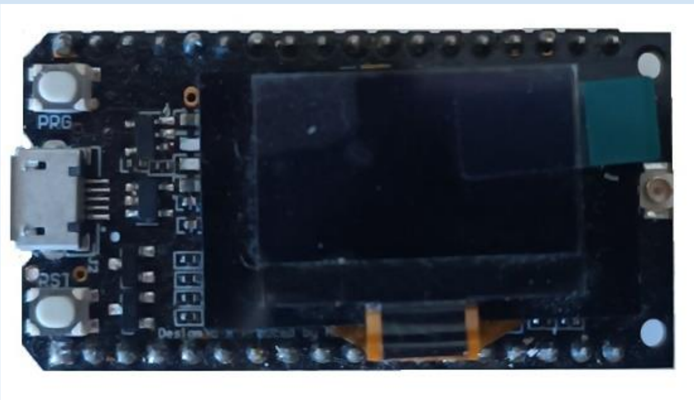
Fig. 2. CPU – TTGO@ESP32

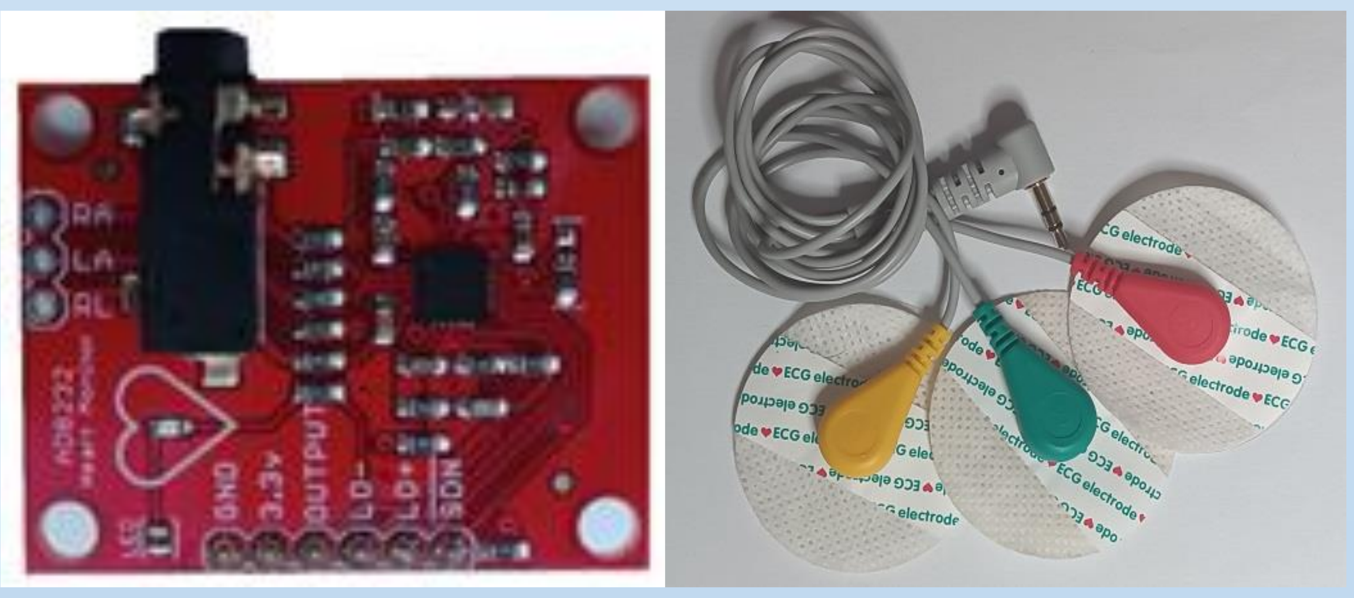
Fig. 3. AD8232 ECG sensor & a set of three electrodes of low-cost ECG sensor

Experimental Setup

To achieve the portability of the device, a small form factor plastic box (110mm x 60mm x 30mm) was used, while powering the device is possible even with a mobile phone charger. The final composition of the low cost electrocardiograph with all its components (microcontroller, ECG sensor and sensor electrodes), is shown in Figure 4.

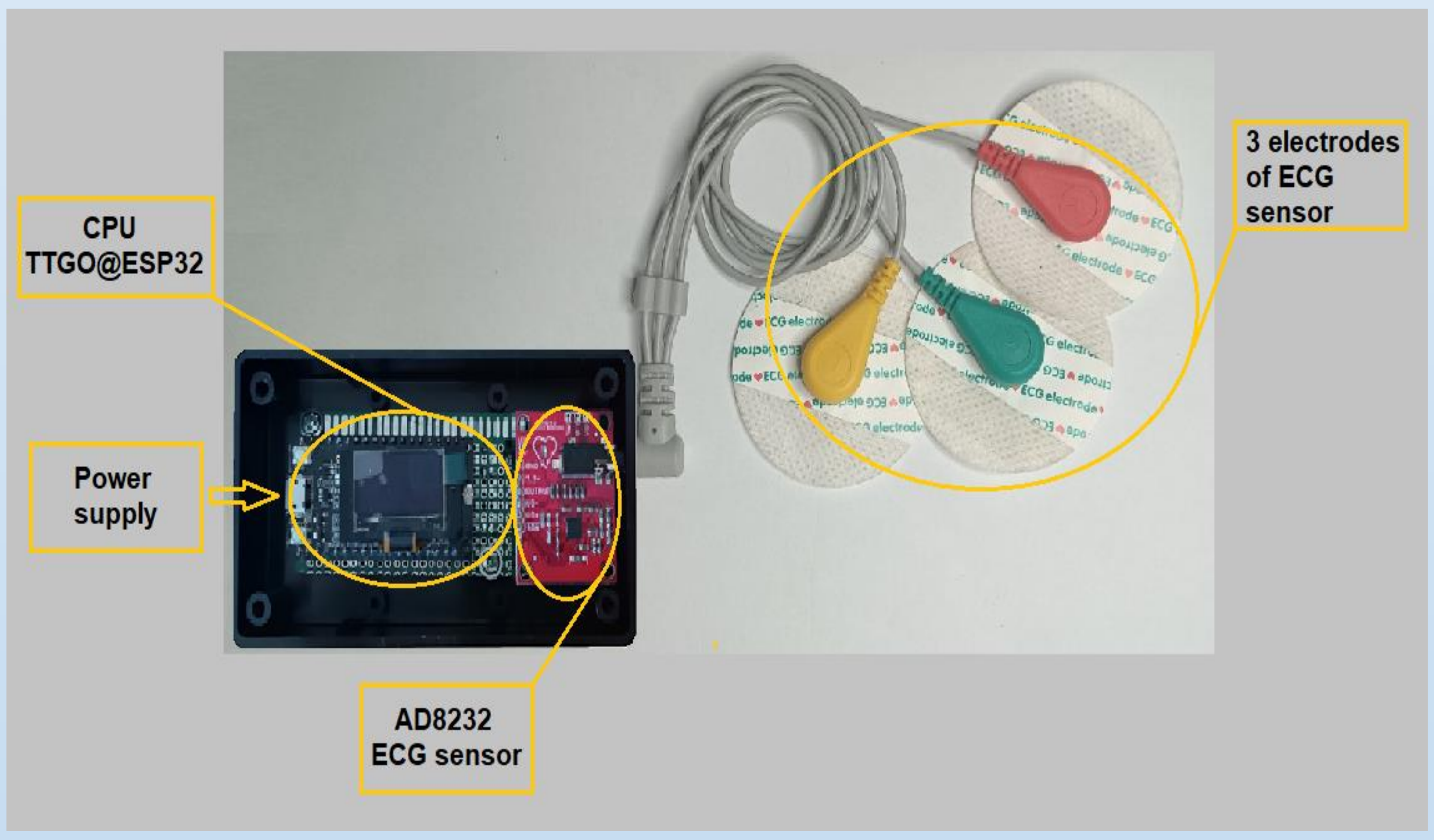

Fig. 4. The complete construction of the low-cost electrocardiograph

The information system is based on an open source operating system (Linux), while two open source server applications are running on it. The first server supports an open source database, while the other server supports web-based software for data visualization. In our work, InfluxDB was chosen as the database, because it is designed strictly for time series data and data visualization for the end user is done through a web page on the internet, using the Grafana lab software.

Experimental Results

According to the operation of the software inside the microcontroller, a packet with measurements is created with 16.384 measurements, each taken 500us apart from the previous one. Every packet results to be about eight seconds long. The package of measurements is then formatted appropriately, and sent to the database via the Wi-Fi. The raw data of the measurements are shown in Figure 5. It can be noticed that the cardiogram contains a lot of signal noise in respect to Figure 1. Both for research and evaluation purposes, the moving average method was applied in different interval values. The Figures below show the results for different intervals. The Figures 6, 7, 8, show the corrected signal with intervals of 50, 100 and 200 points, respectively.

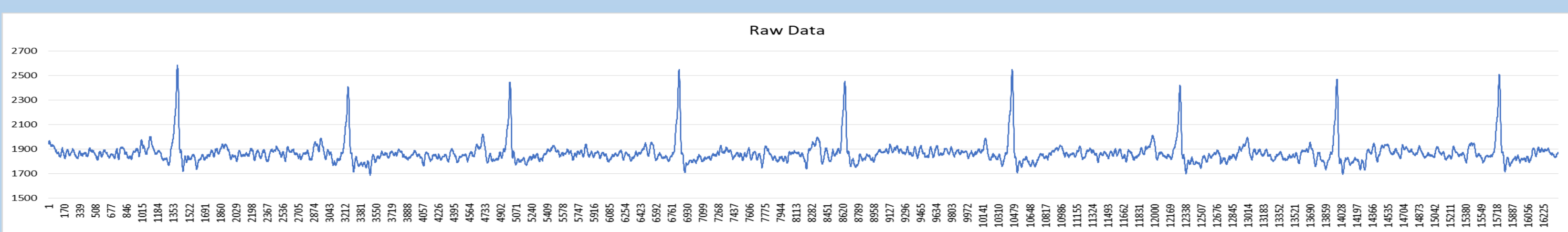

Fig. 5. Raw measurements of low-cost ECG.

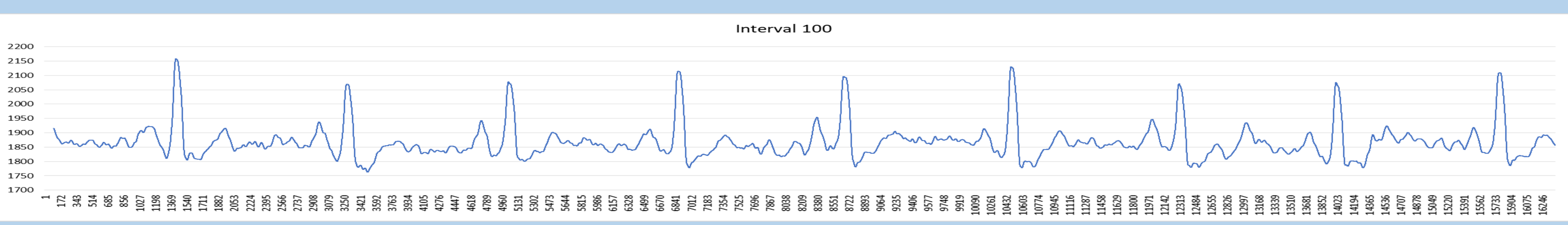

Fig. 6. Corrected measurements by moving average method (Interval = 50 points).

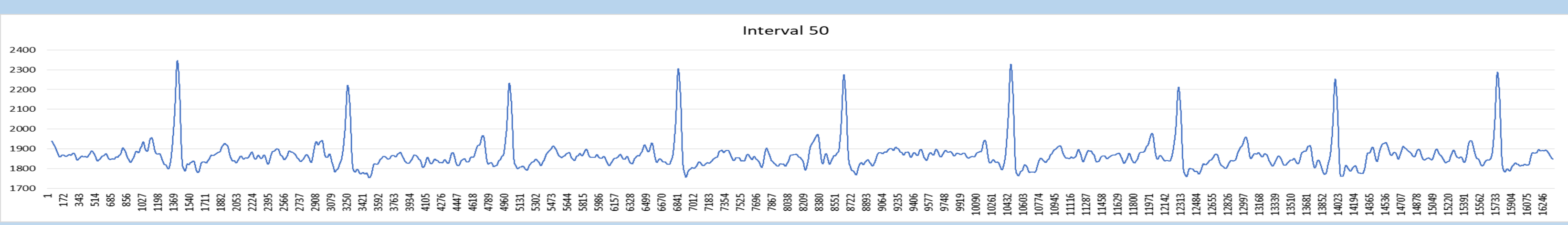

Fig. 7. Corrected measurements by moving average method (Interval = 100 points).

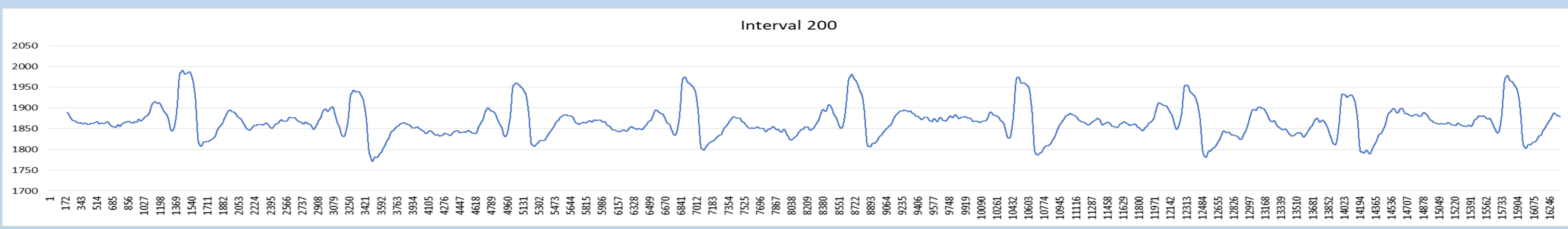

Fig. 8. Corrected measurements by moving average method (Interval = 200 points).

Through the Grafana software, a healthcare provider can see the results of the measurement as shown in Figure 9.

Fig. 9. Grafana, ECG measurements dashboard

Conclusions

Health is a shared good, and technology should support medical prevention. This work introduces a low-cost electrocardiograph system, including a measurement device and information system, allowing doctors to remotely monitor a patient's ECG. While it cannot replace professional systems, it serves as a valuable first diagnostic tool for remote areas. The system performs well in real time, and signal noise correction reveals essential parameters for medical interpretation. Low-cost components, like CPUs and sensors, have broad potential in healthcare. Further development, especially using open-source software, could significantly advance these systems as lifesaving diagnostic tools.