Design of a Remote Vital Parameters Monitoring System Employing a Novel Approach for ECG Peaks Detection

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Background and Objectives

Today, telemedicine networks are increasing their impact on society, proving the possibility of reducing hospitalization of patients when it is not absolutely necessary. According to the World Health Organization (WHO) [1], the field of cardiopathies has a huge impact worldwide in terms of mortality. At the same time, it is one of the not so many fields that gives the possibility to be held remotely. The objective of this work is to realize a system that guarantees the remote monitoring of vital parameters of patients suffering from cardiopathies, in an effective way, thus providing a continuous and real time data transmission between the local portable station and a remote collection block. In fact, many remote monitoring systems collect and transmit data only once or a few times a day. In addition, a peak detection algorithm has been developed to detect the most prominent peaks of the electrocardiographic (ECG) signal, R, T, P wave peaks.

Materials and Methods

The system is constituted by three main blocks, as introduced in [2]:

- Local wearable data acquisition block: An ESP32 dual-core microcontroller embedded in a D1 mini board was used. Using a real-time operating system (FreeRTOS), it can simultaneously acquire data (by core 0) and transmit data (by core 1) using an appropriately sized queue. As sensing units, an AD8232 for ECG and HR acquisition, a MAX30100 for oxygen saturation and a DS18B20 for body temperature control were used.
- Remote data collection and processing block: consisting of a Raspberry Pi3 communicating with the local block via MQTT protocol. Here, the collection block acts as a *Broker* and the local one as a *Publisher*.
- Remote laptop for data analysis: responsible only for data display. Communicates with the collection block through sockets.

A Matlab simulation was carried out before the development of the elabo- rate code on the side of the collection block. At the moment, the local block simply sends data packets to the collection block. The latter is stored and then processed offline.

Results

It has been verified that the communication link between the local and the remote collection blocks is sufficiently reliable and close to the real hypothetical application, with a PLR=0.021% (Packet Loss Ratio).

The ECG is the most important signal and is acquired continuously, while body temperature and oxygen saturation are acquired once an hour according to the sampling frequency of the MCU. The developed algorithm starts from a literature one [3] for the detection of R peaks, with a successive comparison through an envelope application and successive thresholding, for the detection of T, P peaks. Considering this signal (Fig. 2, 3), the corresponding TPR (True Positive Rate), Positive Predicted Value (PPV) are:

- $TPR_R = 0.88$, $PPV_R = 1$
- $TPR_T = 0.81$, $PPV_T = 0.895$
- $TPR_P = 0.794$, $PPV_P = 1$

Conclusions

This system, although not yet ready to be used in a clinical trial, proposes a new approach both in terms of data acquisition and elaboration, although the ECG signal elaboration algorithm should be refined in terms of thresholds.

In addition, the authors are committed to the addition of new modules to assist the patient, such as, but not limited to, vocal verification of the patient's health status.

References

[1] Link: https://www.who.int/health-topics/cardiovascular-diseases

[2] Di Pinto V, Tramarin F, Rovati L., A Preliminary Prototype of Smart Healthcare Modular System for Cardiovascular Diseases Remote Monitor- ing. 9th EAI International Conference on IoT Technologies for HealthCare, HealthyIoT. Nov. 2022. Springer

[3] Bae TW, Kwon KK. Efficient Real-Time R and QRS Detection Method Using a Pair of Derivative Filters and Max Filter for Portable ECG Device. Applied Sciences. 2019;9(19):4128. doi:10.3390/app9194128

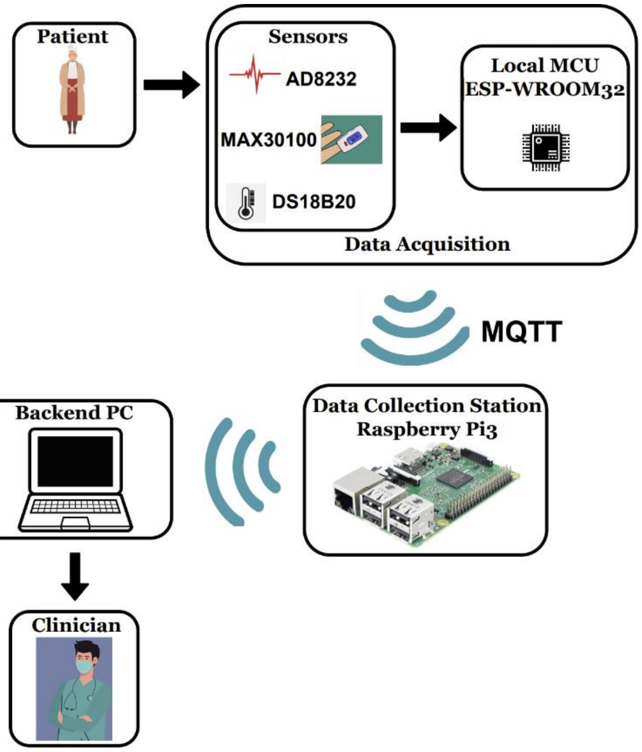

Figure 1: System architecture block diagram

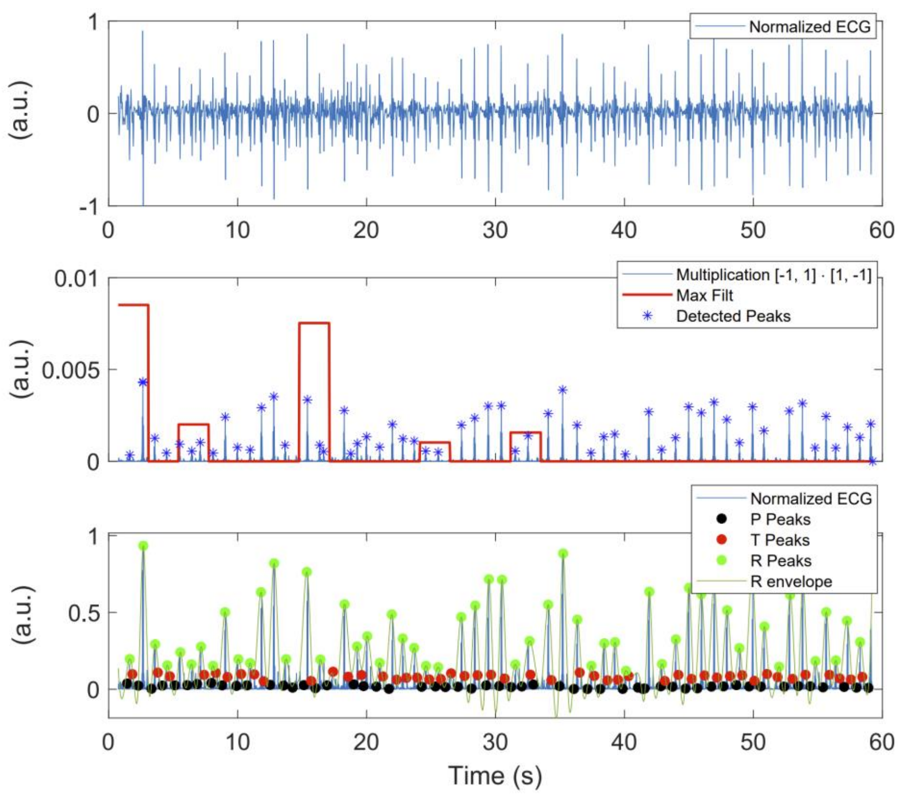

Figure 2: R, T, P-waves detection algorithm result

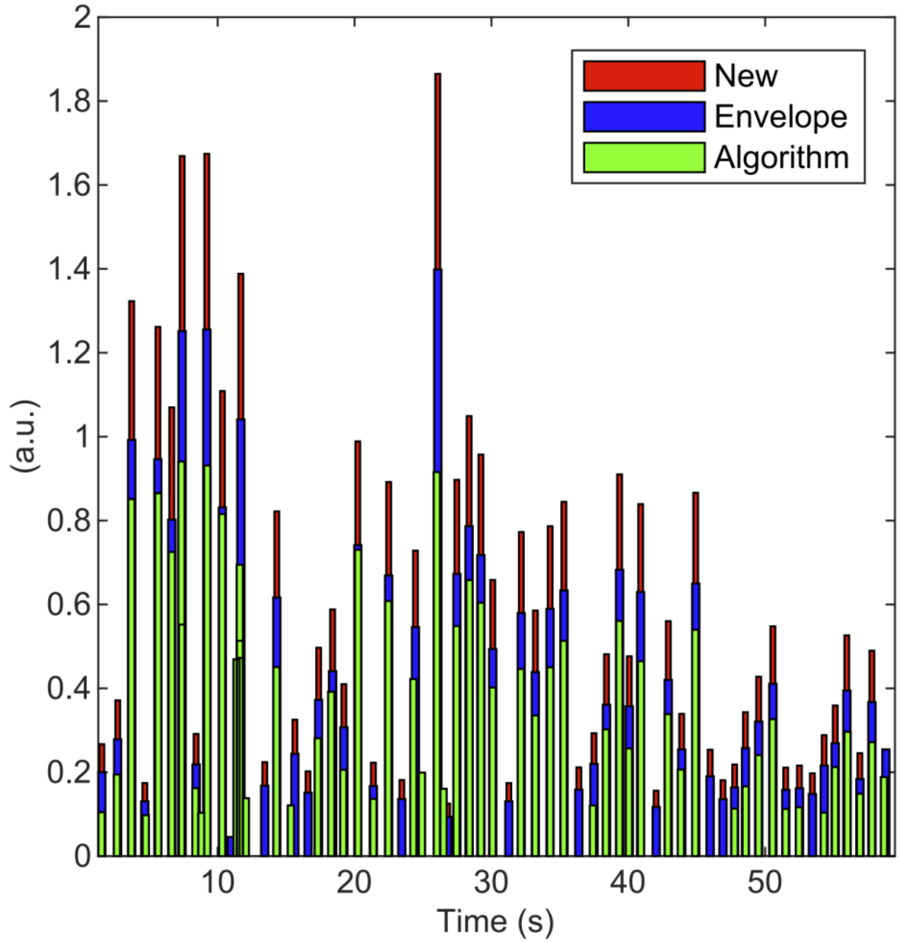

Figure 3: Comparison between developed and literature algorithm for R peaks