Bio-signal Acquisition System Development for Early Warning Score

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Introduction

- Despite the advancements in healthcare monitoring, hospital patients rely on nurses to check vitals and manually compute an Early Warning Score (EWS) [1].
- This warning system uses 6 measurements that include respiration rate, oxygen saturation levels (SpO2), temperature, systolic blood pressure, heart rate, and the Alert Voice Pain Unresponsiveness (AVPU) scale.
- The score is used to detect health degradation before serious complications occur. Errors in the calculations can lead to incorrect diagnosis.
- An Internet of Things (IoT) system is proposed to provide remote access to the EWS.
- The primary measurements of interest for this work are respiration rate, and heart rate.
- These measurements will be transmitted through Wi-Fi to the Gateway.

IoT System Structure

The entire system consists of three layers including the cloud, the gateway, and the sensor network [2].

Sensors and Hardware

Sensors can be placed into three separate categories [2]:

1) Environmental – Monitors external parameters, such as temperature.
2) Activity – Monitors movements, such as a steps.
3) Medical – Monitors vital signs, such as respiration and heart rate.

Primary Hardware Components:

Accelerometer

ADXL362

Pulse Oximeter and Heart Rate Sensor

MAX30100

Wi-Fi Module

ESP8266 Thing Development Board

Methodology

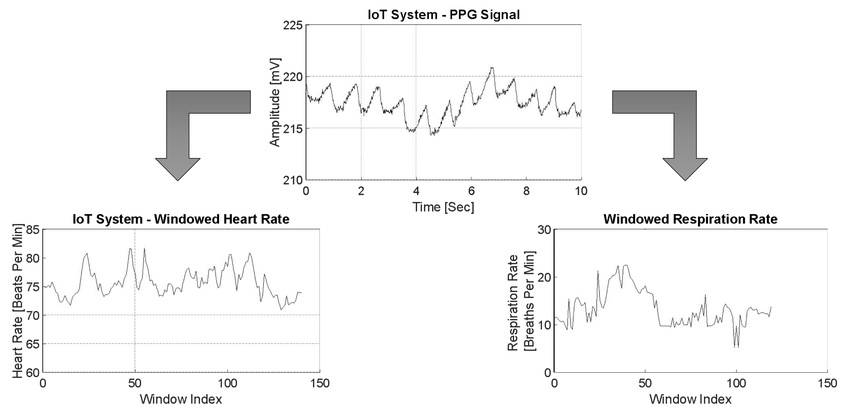
Heart Rate Extraction Process	Respiration Rate Extraction Process
• Window • Filter • Peak Detection • Compute Peak Period • From Peak Period Compute Beats Per Minute	• Window • Filter • Peak Detection • Interpolation • Average • Peak Detection • Compute Peak Period • From Peak Period Compute Breaths Per Minute

The method for extracting the heart rate and respiration rate were similar. Both required filtering, windowing, peak detection, and period calculation between peaks. The major difference between the heart rate and respiration rate were the interpolation performed on heart rate peaks and valleys, and the averaging process for the two interpolated signals to find the respiration signal.

In terms of filters used, we decided on a Butterworth bandpass filter. We used a low cutoff frequency of 0.15 Hz and a high cutoff frequency of 2.34 Hz. The cut off frequencies were chosen to detect heartbeats ranging from 40 to 140 beats per minute, while still being able to extract a low respiration frequency of 9 breaths per minute.

Results

The raw PPG signal, extracted from the MAX30100 sensor from the IoT system we developed, was put through the algorithm described above.



The windowed results cover a 3 minute set of data with the heart rate hovering around a normal region for a patient at rest. Slight jumps in the heart rate can be attributed to shifts in the patients finger placement on the sensor. Additionally, the respiration results reflect the patient's breathing pattern while at rest.

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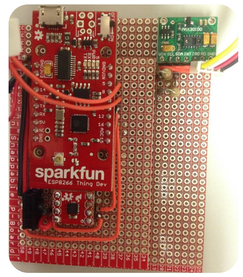
Validation

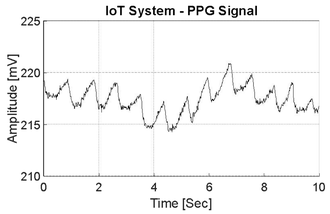
The validation process consisted of comparing results from the following devices:

IoT system

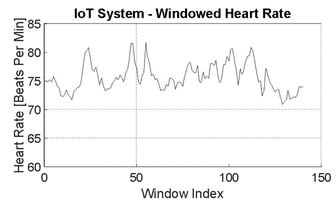


Fingertip Pulse Oximeter

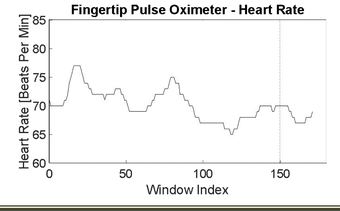
The following graph is a 3 minute long PPG signal, using a sampling frequency of 100 Hz:



The heart rate below was computed using the previously described method:



The final step of the validation process involved comparing the method results to the measurements coming from the fingertip pulse oximeter:



Summary and Conclusions

- Our method for processing the signal produces comparable results to that of an actual heart rate monitor.
- The manufactured pulse oximeter's clamp produces a precise PPG signal, and work needs to be done to stabilize the finger on the MAX30100 sensor.
- Respiration and heart rates were successfully computed and extracted.

References
1. Morgan et al. An early warning scoring system for detecting developing critical illness. Clin Intensive Care, 8(2):100, 1997.
2. Rahmani, A., Nguyen Gia, T., Negash, B., Anzanpour, A., Azimi, I., Jiang, M. and Liljebreg, P. (2017). *Exploiting smart e-Health gateways at the edge of healthcare Internet-of-Things: A fog computing approach - ScienceDirect*. [online] Sciencedirect.com. Available at: http://www.sciencedirect.com/science/article/pii/S0167739X17302121 [Accessed 10 July 2017].