Wireless Respiratory and Heart Rate Sensor

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Introduction

Several emerging technologies, such as millimeter wave (mmWave) and ultra-wide band (UWB) promise to accurately monitor several key vital signs in real time. This data is instrumental for ensuring proper care of patients in a clinical setting. This project analyzed this technology, and created a functional prototype which provides data analysis relevant to machine learning applications for classifying dangerous abnormalities. Specifically, an algorithm to compute the heart rate variability (HRV) is developed.

Why HRV?

Heart rate variability is the measurement of the variation of time between heart beats. Modified (typically lowered) HRV has been associated with a range of clinical outcomes, including increased mortality following myocardial infarction [1]. HRV has been shown to be a significant feature for classification and prediction of heart rate abnormalities [2].

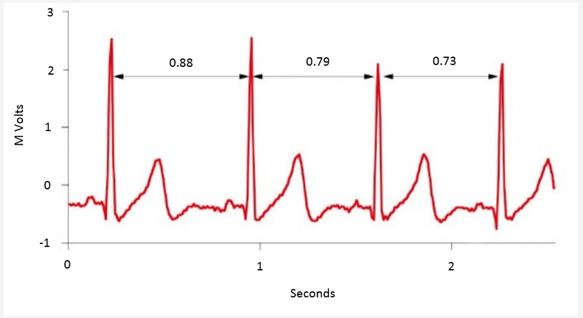

Figure 1: A visualization of heart rate variability.

Goal

The goal of the project is to develop a prototype system to wirelessly monitor heart rate, breathing rate, and HRV. Emphasis is placed on obtaining an accurate HRV metric, given its importance in classifying dangerous heart abnormalities.

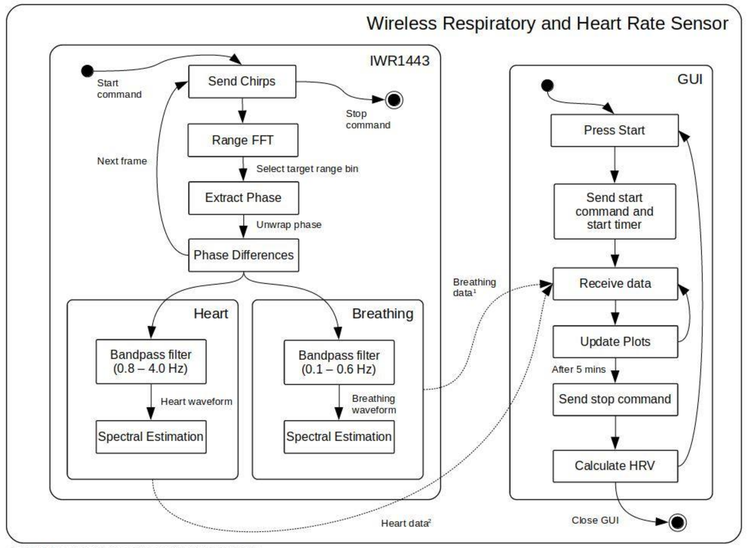

Figure 2: Block diagram illustrating the system design.

Design

The design consists of two distinct modules:

1. Texas Instruments' IWR1443BOOST evaluation board and associated firmware [3,4]. This module is used for data collection and rate computations.
2. The PC software environment, using MATLAB and the MATLAB App Designer [5]. This module consists of a MATLAB program which computes the HRV data using three different methods, as well a graphical user interface to display data to the user.

- The first module sends packets of data via UART to the MATLAB program. The heart and respiration rates are calculated in real time using a 15-second window. The HRV is calculated after 5 minutes of data has been gathered.
- The HRV is calculated in three different ways, yielding an estimate of the 5 minute RMSSD, SDNN, and HTI values. Having each of these values gives a more robust picture of the true variability.

Results and Discussion

- The hardware sensor is able to accurately detect heart and respiration rates in real time up to 1.25m away, through clothing.
- The HRV values are computed algorithmically and presented on screen as RMSSD, SDNN, and HTI.
- A GUI provides user-friendly data output, and facilitates the collection of HRV data.
- The heart and respiration rates, as compared to other monitoring devices, provide an accurate reading.

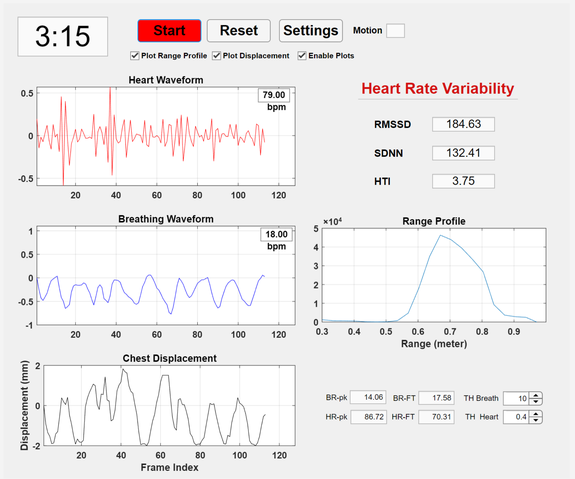

Figure 3: A view of the graphical user interface.

Conclusion

Wireless mmWave sensing technology was used to create a contactless vital signs monitoring system. The system provides real-time metrics for heart and respiration rate, as well as a 5-minute estimate of the HRV in the form of HTI, SDNN, and RMSSD. The system includes a hardware sensor array as well as a MATLAB GUI interface.

References

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[2] - Vyas, P.; Pandit, D. *Heartbeat Abnormality Detection using Machine Learning Models and Rate Variability (HRV) Data.* Preprints 2018, 2018070488 (doi: 10.20944/preprints201807.0488.v1).

[3] - Texas Instruments, "IWR1443BOOST evaluation module mmWave sensing solution," User's Guide, May 2017 [Revised May 2020]. [Online]. Available: https://www.ti.com/lit/ug/swru518d/swru518d.pdf

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