Automated Smartphone Emergency Callouts for Heart Disease Sufferers

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Existing solutions

St John's Medical Alert Bracelet

Wall Mounted Emergency Button

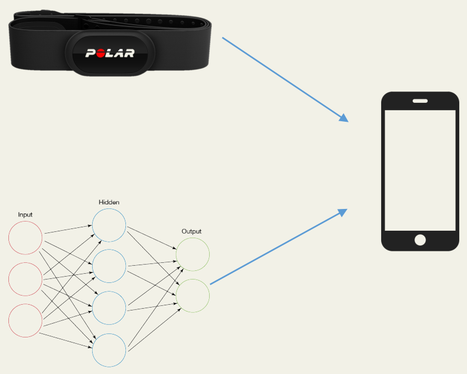
Problem

Heart arrhythmia is a chronic condition that often affects heart disease sufferers. Conditions such as ventricular fibrillation cause rapid, electrical impulses that require immediate medical attention.

Current solutions to issue emergency callouts during episodes are manual in nature, such as home medical alarms and medical bracelets. However, it has been proven in research that human misjudgment is a major factor in cardiac arrhythmia related death.

Thus, the aim of this project is to develop an automated heart alert system, using:
- A cost efficient heart monitoring wearable
- An artificial neural network to classify heart state
- A smartphone app to issue emergency callouts, with real-time heart monitoring and classification

Proposed solution



HRM + Neural Network + Smartphone App

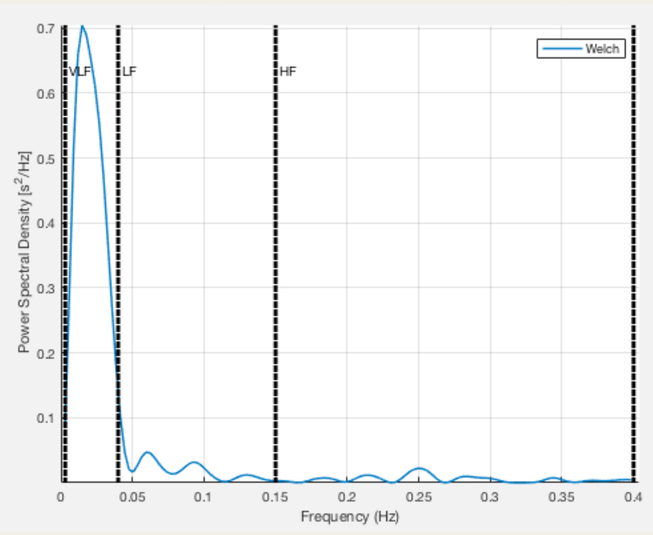
Real-time Heart Monitoring

ECG-based Monitoring ✗
- Most accurate in clinical contexts, but unsuitable for ambulatory use due to complicated electrode placement, messy leads and noise induced while walking.

PPG-based Monitoring ✗
- More portable than ECG, but has accuracy issues, and poor ease of use due to requiring a pulse oximeter on finger at all times.

HRV-based Monitoring ✓
- Research linking heart activity to HRV parameters in the frequency domain. Research showing success in classification of heart states via HRV.
- Low-cost, commercial solutions available. The Polar H7 Belt R-R intervals shown to correlate to ECG QRS complexes at r = 0.8-0.996 (1 confidence interval).

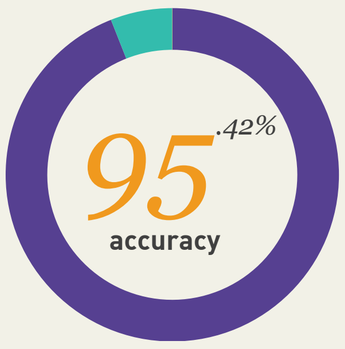
Power Spectral Density of HRV: A Visual Representation



HRV of a 2-minute ventricular tachycardia episode, Courtesy of Physionet's WFDB Matlab package

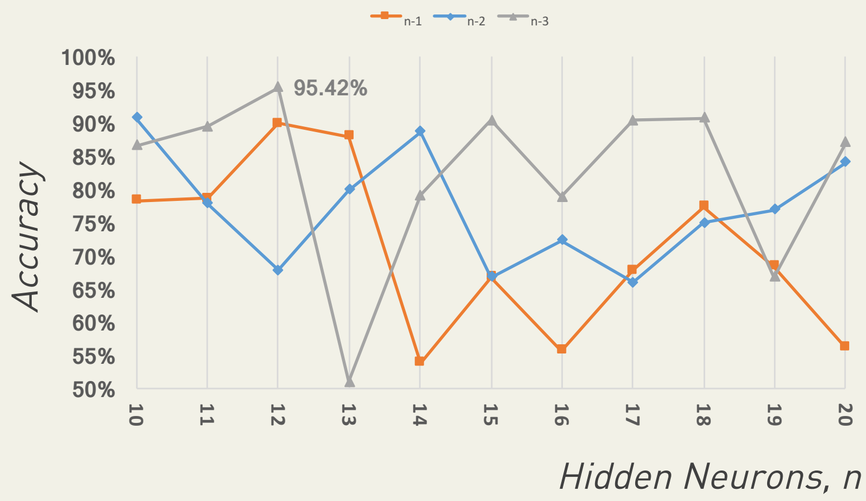
Artificial Neural Network

Using a Physionet dataset, a neural network was trained to detect the onset of ventricular tachycardia with 95.42% accuracy, under binary classification. Model consisted of 2 hidden layers, and a sigmoid activation layer.



Confusion Matrix

N = 242	Predicted: No VT Onset	Predicted: VT Onset
Actual: No VT Onset	133	2
Actual: VT Onset	9	96

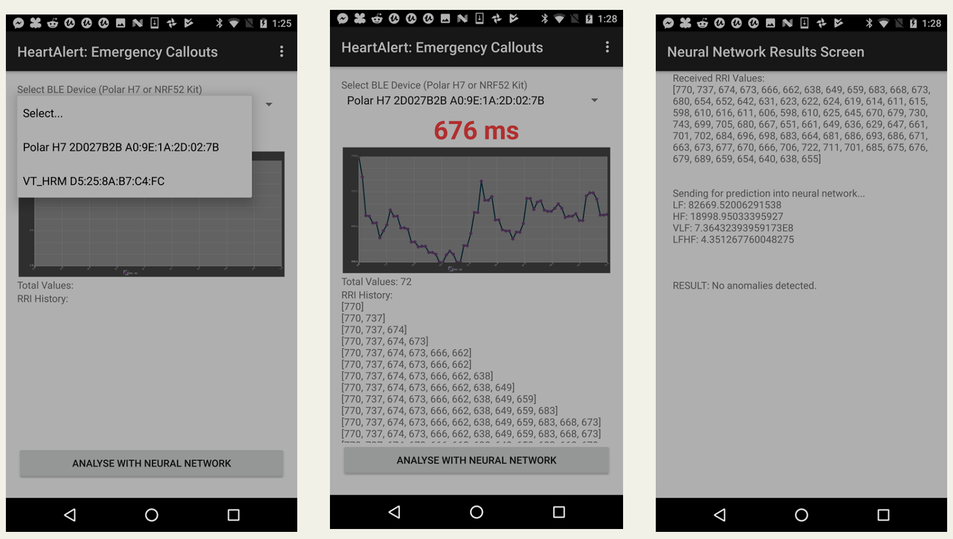


A heatmap of neuron configurations was used to decide on the exact architecture. 'n' denotes the number of neurons in the first hidden layer, and 'n-x' (where x is a number from 1 to 3) denotes the number of neurons in the 2nd hidden layer.

Smartphone App

The developed Android app connects Bluetooth Low Energy devices that expose the Bluetooth SIG Heart Rate Service, and reads R-R interval data from received packets. The app is compatible with the Polar H7 belt, as well as an nRF52 BLE development kit used for testing undesirable heart states.

R-R intervals are then sent to be processed to HRV metrics in the frequency domain, using the publicly available hrv-lib Java library. From this project, a successful pull request was made to the original library developer's repository to expand the functionality of hrv-lib, to fit the needs of this project.



Screen 1:
Selection of BLE device.

Screen 2:
Ongoing measurements of R-R intervals, with visual display. Once 60+ samples are measured, R-R interval data is sent for processing.

Screen 3:
Data is processed into four HRV parameters. Results are placed as inputs into the trained classifier, and a judgement on heart condition is given.

Summary & Future Work

HRV metrics provide an ambulatory alternative to ECG-based readings, which allows for closer day-to-day monitoring of heart disease sufferers at risk of arrhythmia episodes. The developed system is kept low-cost and can be operated easily.

Feasibility has been established, but more development work will need to be conducted to ensure that false negatives are completely absent, due to criticality of the system. More work can also be done to classify more undesirable heart states, such as atrial fibrillation and supraventricular tachycardia.

Image References:
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