Interpreting Body Sensor Networks (BSNs) for Sensor Abnormalities

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Why Body Sensor Networks?
- BSN: A network of bio-sensors
  - Wearable/implantable
  - Wireless communication
  - Positioned strategically on the body
- Applications
  - Health monitoring, Disease diagnosis
  - Field agent monitoring (fire fighters, rescuers, soldiers)
- Challenges
  - Reliable monitoring
  - Novel approach for signal quality validation

Design Objective

Determine system failure based on comparison of heart cycles from various cardiovascular signals.

Main Tasks and Progress
- Device Acquisition (Completed)
  - ECG Unit, Blood Pressure Unit (replaced by third ECG device), SpO2 Unit
- Signal Processing (Completed)
  - Peak extraction for ECG, SpO2
  - P-P Period comparison
  - Correlation analysis
- Define Detection Criteria (In progress)
  - Multiple Recordings from various subjects at different times
- GUI Interface (In progress)

System Overview

Signals Validation Scheme

* Threshold is the maximum allowed p2p variation
* It is defined through system training and iteratively every fixed amount of time
Main components of an ECG heart beat

- ECG reflects the cardiac electrical activity over time
- Typical ECG Heartbeat consists of:
  - P-wave, Atrial Contraction
  - QRS complex, Ventricle Contraction
  - T-wave, re-polarization of Ventricles
- Recordings with a set of electrodes on the body surface.

ECG as Vital Sign

ECG R Peak Detection

- ECG signals are noisy
  - Filtering requirements
  - Complex Peak Detection Algorithm
- Energy concentrated around R-peaks
  - Higher Amplitude
- Output: RR interval in seconds

The Saturation of Peripheral Oxygen (Sp\textsubscript{o2}) Sensor and Corresponding Waveform

- Percentage of arterial hemoglobin in the oxyhemoglobin configuration
- Non-invasive (blood sample not required)
- Continuous periodic waveform
- 75 Hz sampling rate

Peak Detection Algorithm for the Sp\textsubscript{o2} Signal

- Iterative Local Maxima algorithm
  - Scan window iterates and extracts the index and amplitude of peak
- Output:
  - P-P periods
  - Figure with original waveform and detected peaks

Sampling and Validation Methodology

- Verify the assumption that there exists a certain correlation between the Peak-to-Peak periods of the different Cardiovascular signals.
- Challenges
  - Transmission delay
    - Hidalgo ECG (Chest), Vernier ECG (Arm), and Sp\textsubscript{o2} (Finger)
  - Sampling Frequencies
    - Hidalgo ECG (256 Hz), Vernier ECG (200 Hz), Sp\textsubscript{o2} (75 Hz)
    - Up/down sampling
- Collect simultaneous data offline from all three devices
- MATLAB function
  - Period estimation
  - Hidalgo data: Down sampling to 200 Hz
  - Sp\textsubscript{o2} data: Up sampling to 200 Hz
Results of Testing and Validation

- Pair wise comparison of P–P Periods via
  - Mean/Mean of Difference
  - Standard Deviation/Standard Deviation of Difference
  - Minimum and Maximum Value
  - Threshold
  - Percentage Error

\[
\% \text{ Error} = \frac{\text{Avg(Mean of Difference)}}{\text{Signal Mean}} \times 100\%
\]

<table>
<thead>
<tr>
<th>Mean of Difference ((\Delta P))</th>
<th>Percentage Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_{\text{SpO2}}) 0</td>
<td>0.765%</td>
</tr>
<tr>
<td>(P_{\text{Vernier}}) 0</td>
<td>0.537%</td>
</tr>
<tr>
<td>(P_{\text{Hidalgo}}) 0</td>
<td>0.537%</td>
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</tbody>
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What is Next?

- Decision Making
  - Rules for Failure Detection
  - Possible Failure Modes
- Testing Failure Modes
- GUI Interface
  - Interactive Display to User