Interpreting Body Sensor Networks (BSNs) for Sensor Abnormalities

Haiyan Xu
Ali Tawfiq

Project ID: 2009153
Supervisor: Prof. K.N. Plataniotis
Administrator: Prof. Hans Kunov

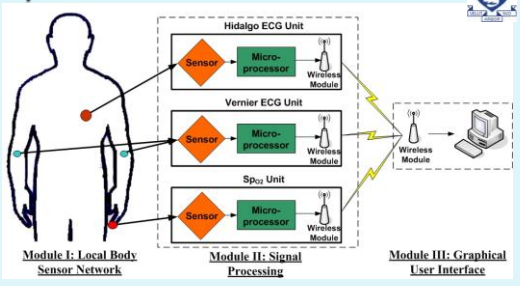
Why Body Sensor Networks?

- 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.

System Overview

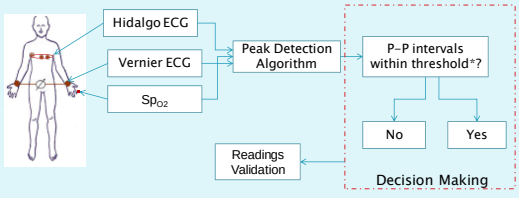


➢ **ECG , Sp_{O2}** suitable for monitoring and diagnosis

Main Tasks and Progress

- Device Acquisition (Completed)
  - ECG Unit, Blood Pressure Unit (replaced by third ECG device), Sp_{O2} Unit
- Signal Processing (Completed)
  - Peak extraction for ECG, Sp_{O2}
  - P-P Period comparison
  - Correlation analysis
- Define Detection Criteria (In progress)
  - Multiple Recordings from various subjects at different times
- GUI Interface (In progress)

Signals Validation Scheme

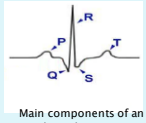


* Threshold is the maximum allowed p2p variation

* It is defined through system training and iteratively every fixed amount of time

ECG as Vital Sign

- 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.

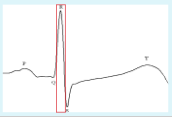


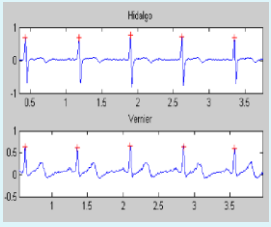
Main components of an ECG heart beat

http://www.vetgo.com/cardio/concepts/images/qrs_durs.JPG

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





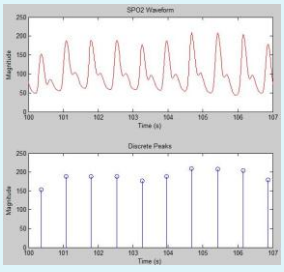
The Saturation of Peripheral Oxygen (Spo_2) Sensor and Corresponding Waveform

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

http://www.nonin.com/_images/products/LargImages/4100.jpg

Peak Detection Algorithm for the Sp_{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

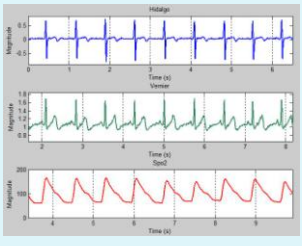


Testing and Validation Methodology

- 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_{o2} (Finger)
  - Sampling Frequencies
    - Hidalgo ECG (256 Hz), Vernier ECG (200 Hz), Sp_{O2} (75 Hz)
    - Up/ down sampling

Testing and Validation Methodology

- Collect simultaneous data offline from all three devices
- MATLAB function
  - Period estimation
  - Hidalgo data: Down sampling to 200 Hz
  - Sp_{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

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

	Mean of Difference (ΔP)			Percentage Error
	Sp_{O2}	Vernier	Hidalgo	
Sp_{O2}	0	0.0057	0.0057	0.765%
Vernier	--	0	0.0023	0.537%
Hidalgo	--	--	0	0.537%

What is Next?

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