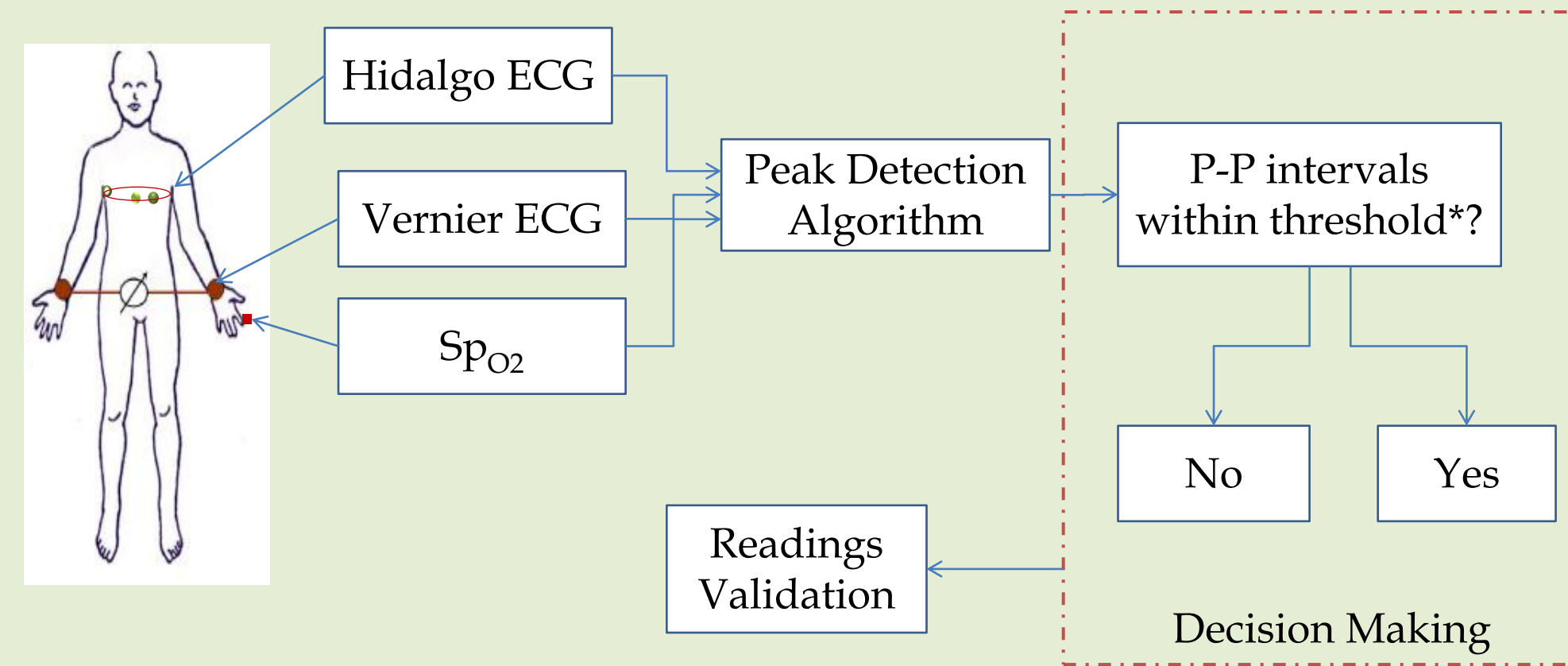


Interpreting Body Sensor Networks (BSNs) for Sensor Abnormalities

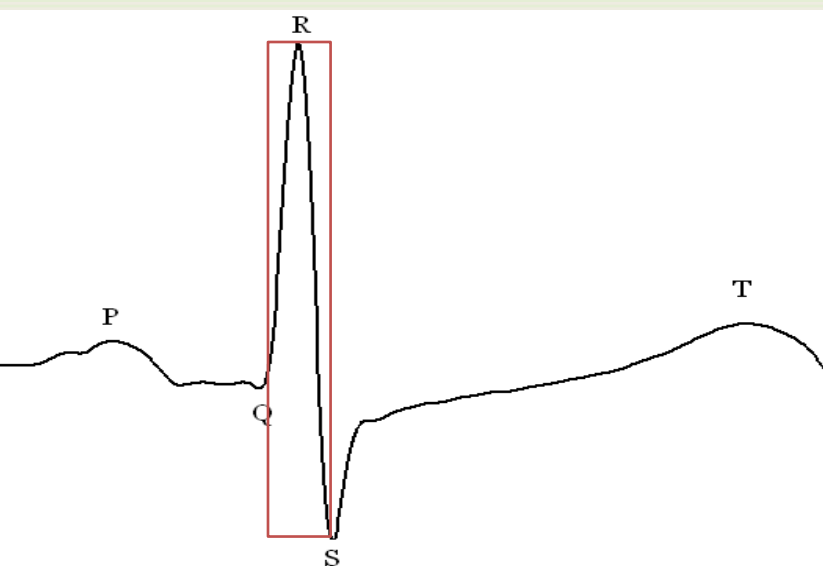
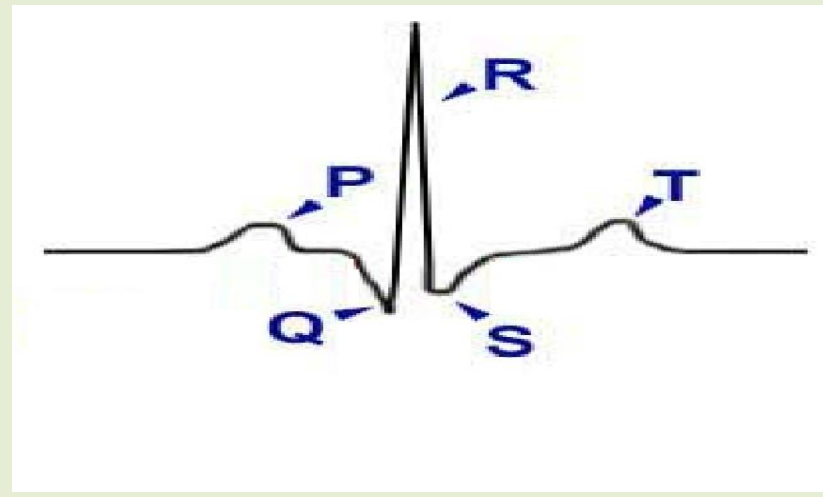
System Design



• Threshold is the maximum allowed p2p variation, It is defined through system training and iteratively every fixed amount of time

Electrocardiogram (ECG)

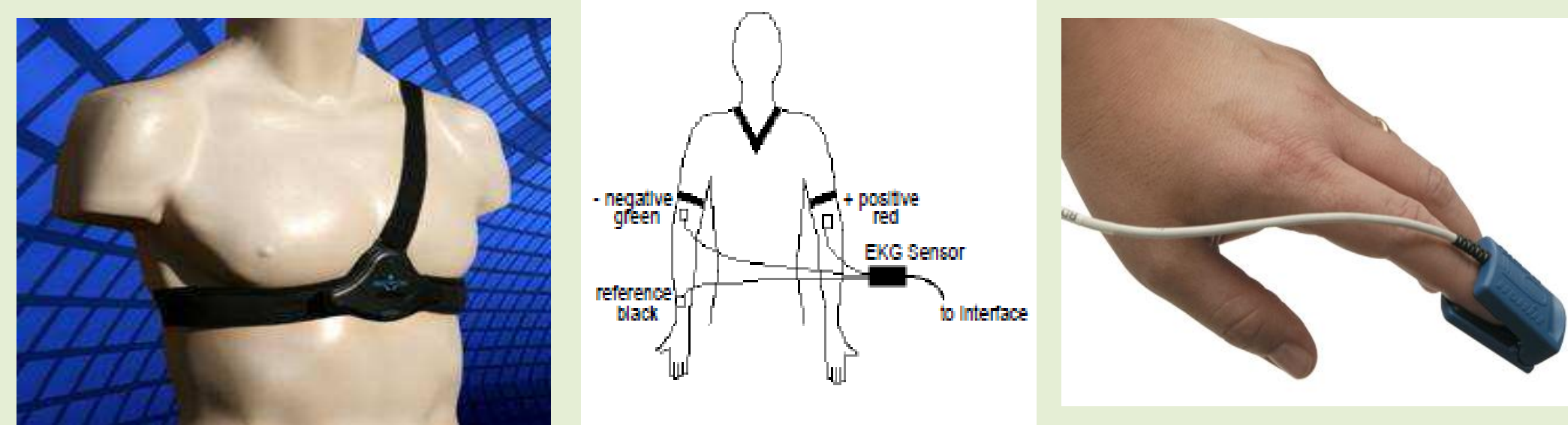
- ECG reflects the cardiac Electrical activity over time
- Typical ECG Heartbeat consists of
 - P wave, Atrial Contraction
 - QRS complex, Ventricle Contraction
 - T wave, re-polarization of Ventricles
- Recording with a set of electrodes on the body surface.



Background

- BSN: A network of bio-sensors
 - Wearable/implantable
 - Wireless communication
 - Positioned strategically on the body
- Applications
 - Health monitoring, Disease diagnosis
 - Field agent monitoring (i.e. soldiers)
- Challenges
 - Reliable monitoring
- Novel approach for sensor signal validation

System Components



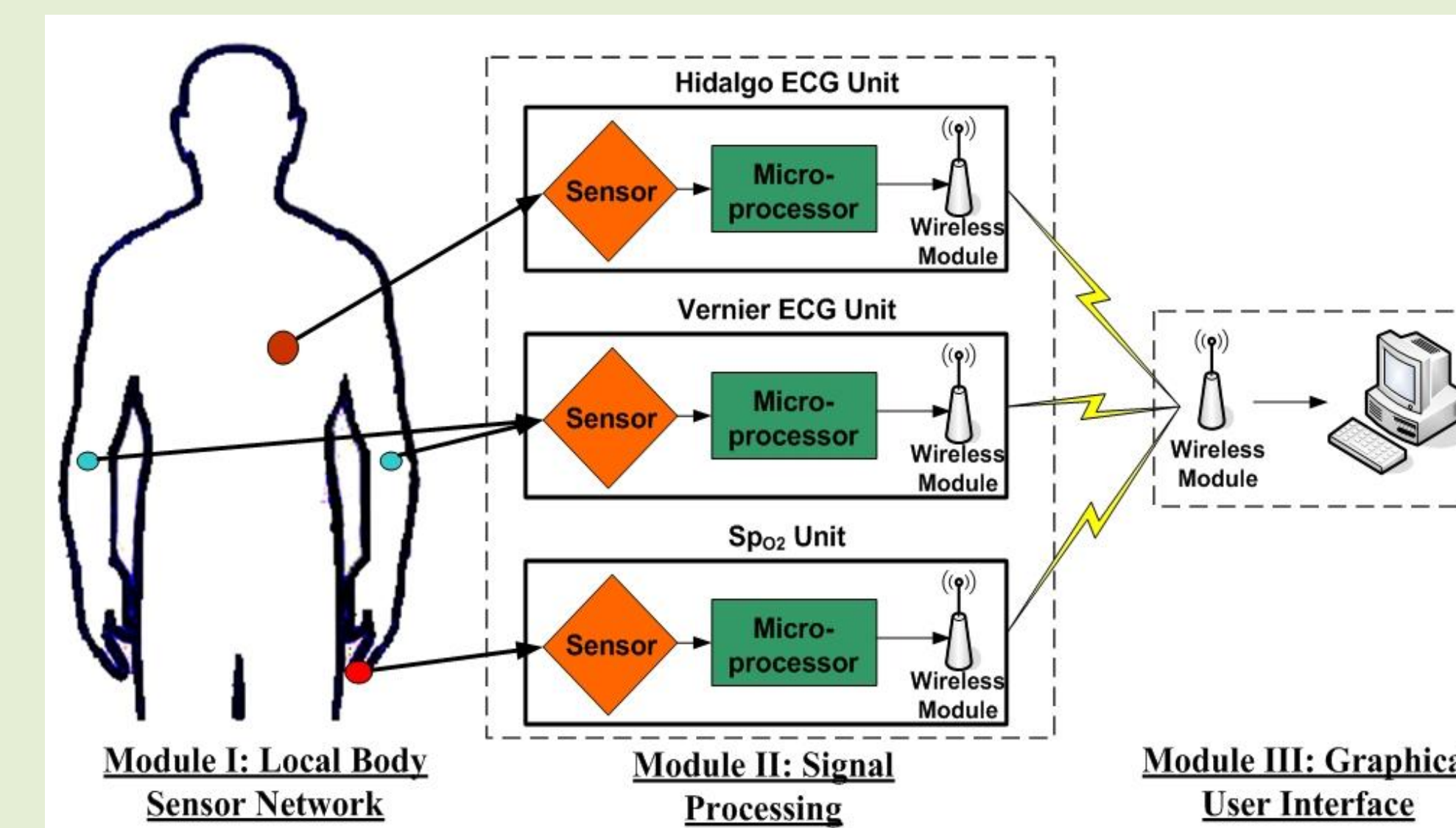
Electrocardiogram (ECG), Peripheral Oximeter (SpO₂)

Objective

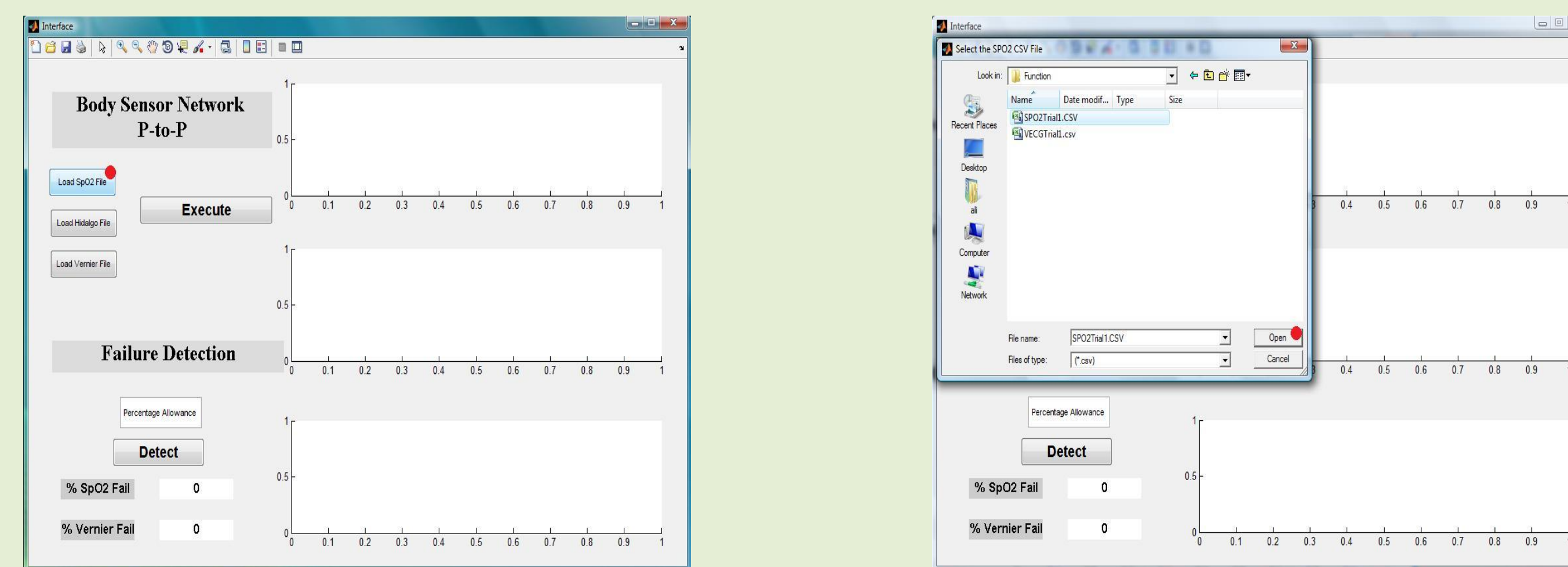
Determine system failure based on comparison of *heart cycles* from various *cardiovascular* signals.

- Cardiovascular signals are universal and can be obtained through primary or secondary sensors
- There exists a certain correlation between the Peak-to-Peak periods of the different Cardiovascular signals.

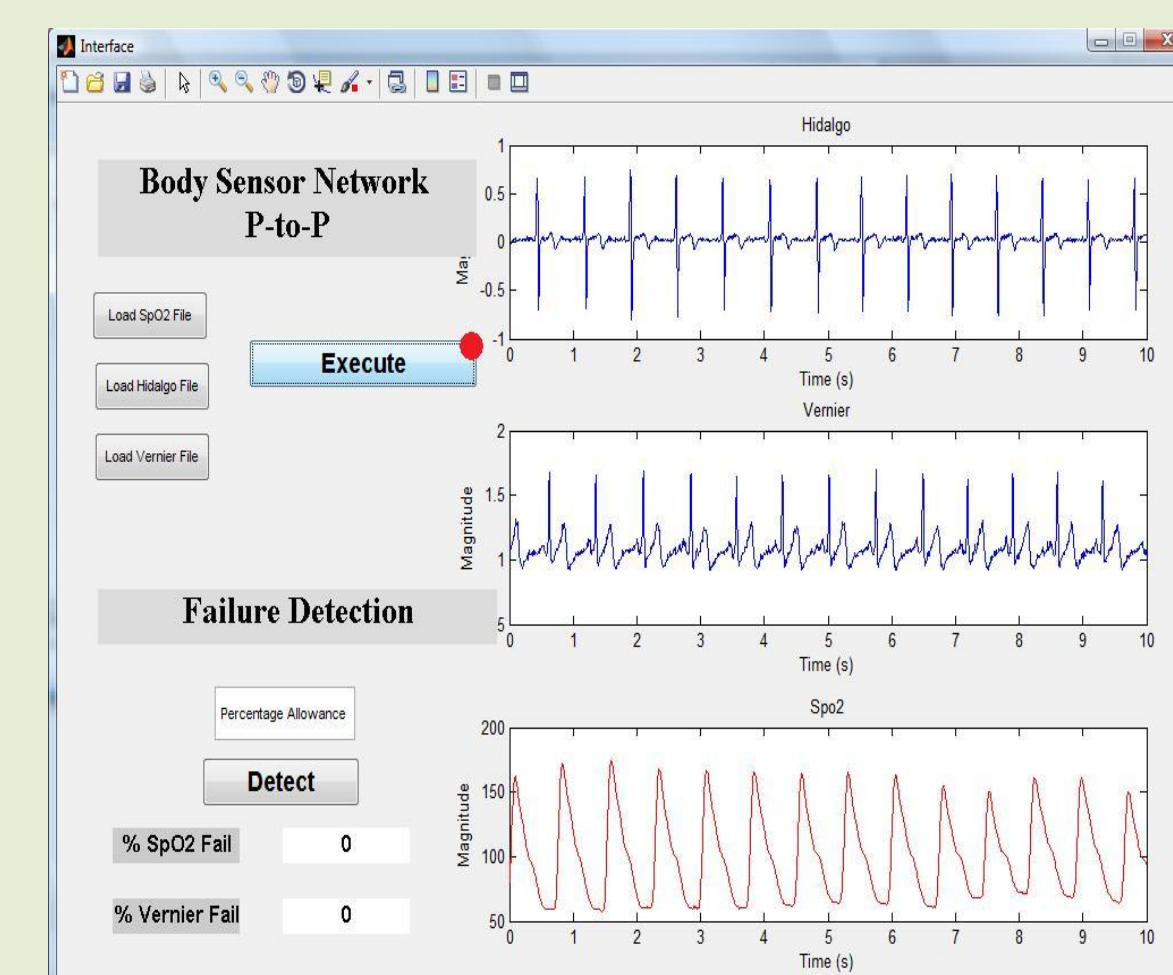
System Overview



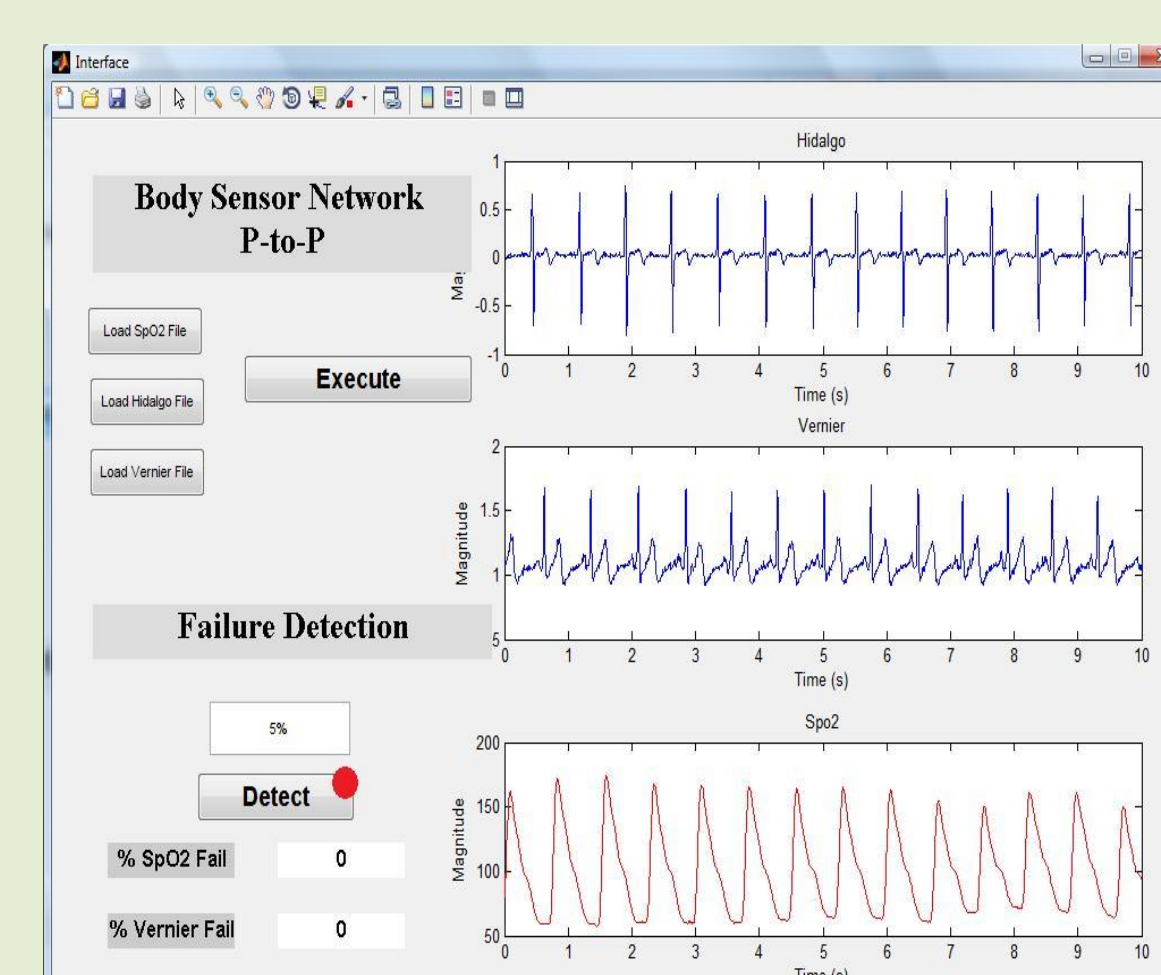
Graphical User Interface



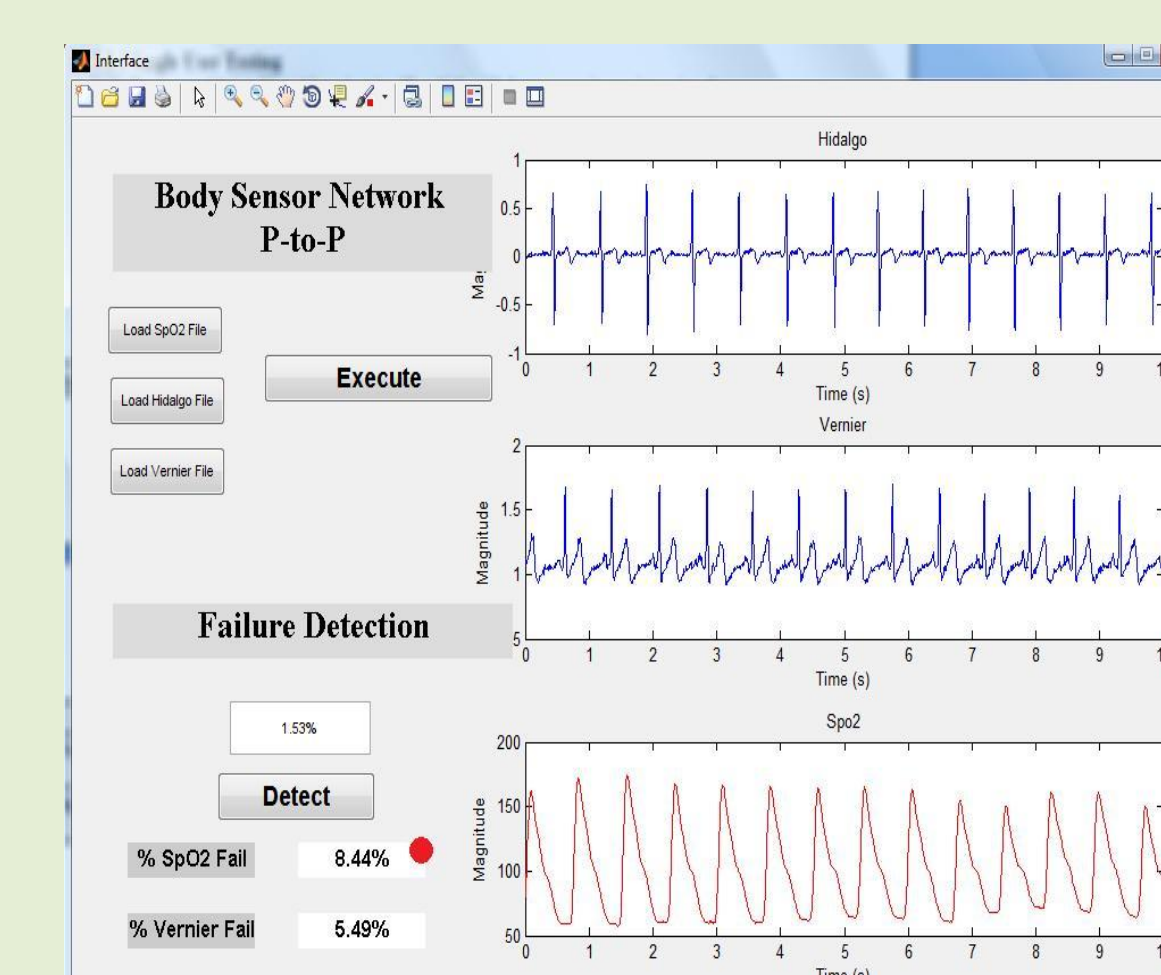
Step 1: Locate the three data files by using the 'Load' buttons



Step 2: Press Execute in order to run the Peak detection algorithm and plot the signals



Step 3: Select a percentage allowance in order to run the Failure detection algorithm



Step 4: Press Detect and the percentage failure will show up in the corresponding boxes

Testing and Verification

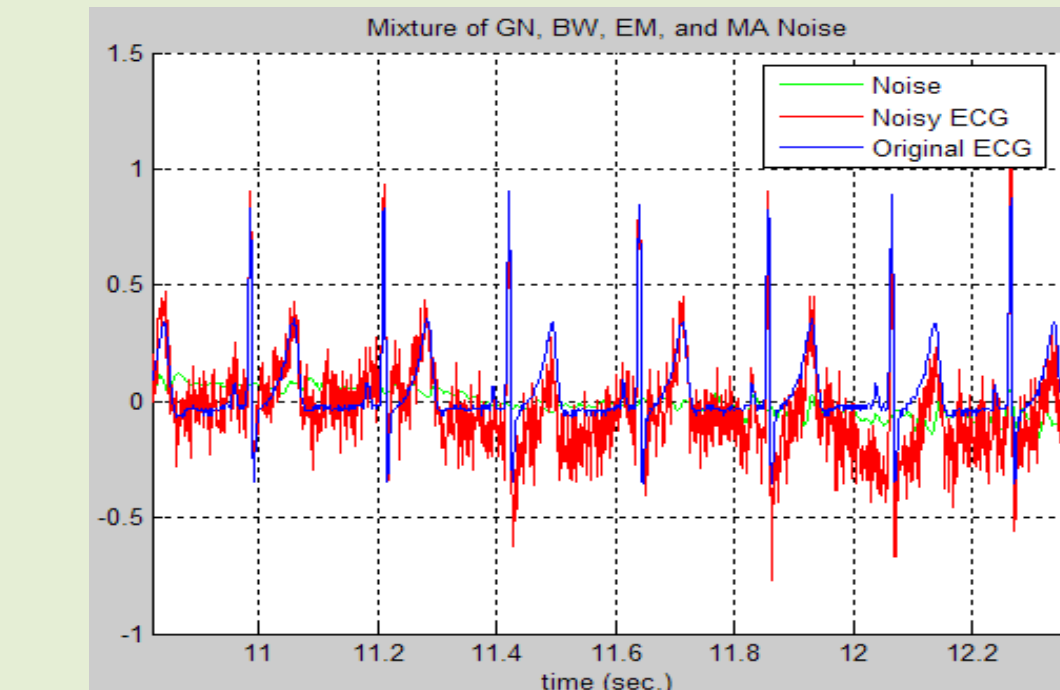
Correlation of Physiological Data

- Confirmed the assumption that there exists a certain correlation between the Peak-to-Peak periods of the different Cardiovascular signals.
- Challenges:
 - Transmission delay
 - Difference in Sampling Rates

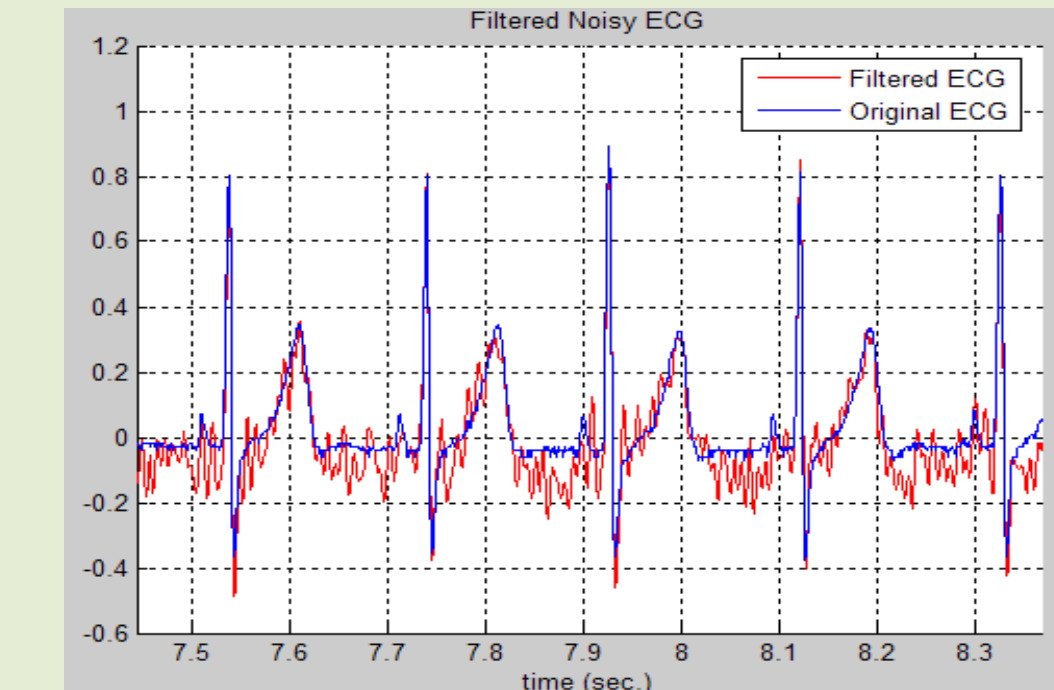
	Mean of Difference			Standard Deviation	STD of Difference			Percent Error	
	Mean	SpO ₂	Vernier		Hidalgo	SPO ₂	Vernier		Hidalgo
SpO ₂	0.745	0	0.0057	0.0057	0.0464	0	0.0047	0.0046	0.77%
Vernier	0.745	--	0	0.0023	0.0451	--	0	0.0017	0.54%
Hidalgo	0.745	--	--	0	0.045	--	--	0	0.54%

Algorithm Robustness

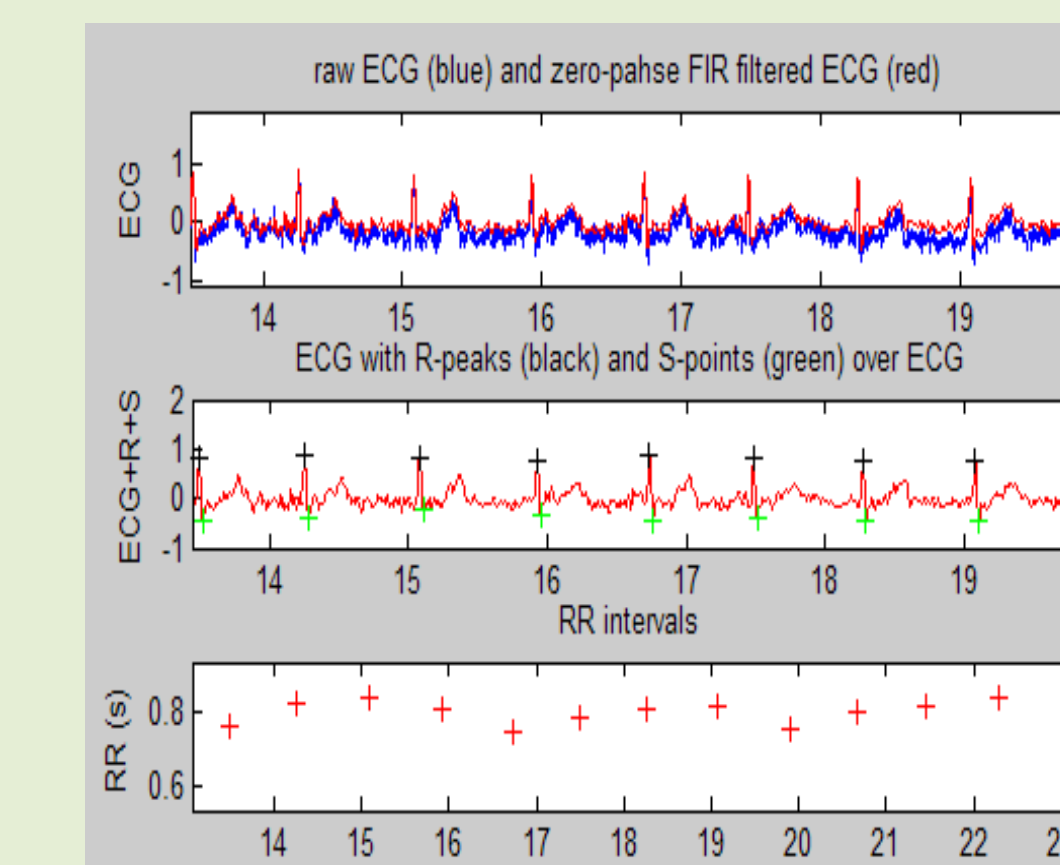
- Introduce artificial noise to the ECG data
- Test the robustness of the Peak Detection algorithm with the introduced noise



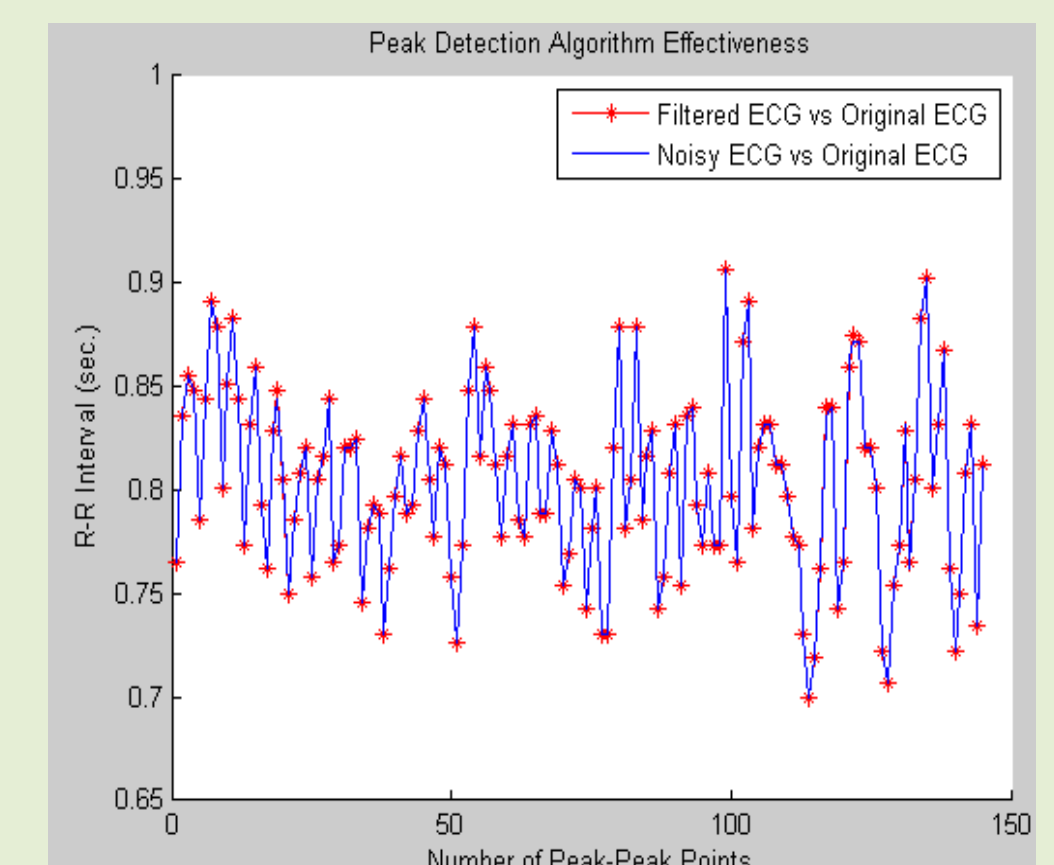
Input ECG Waveform with noise



Pre-processed Noisy ECG Waveform



Peak Detection with Noisy ECG



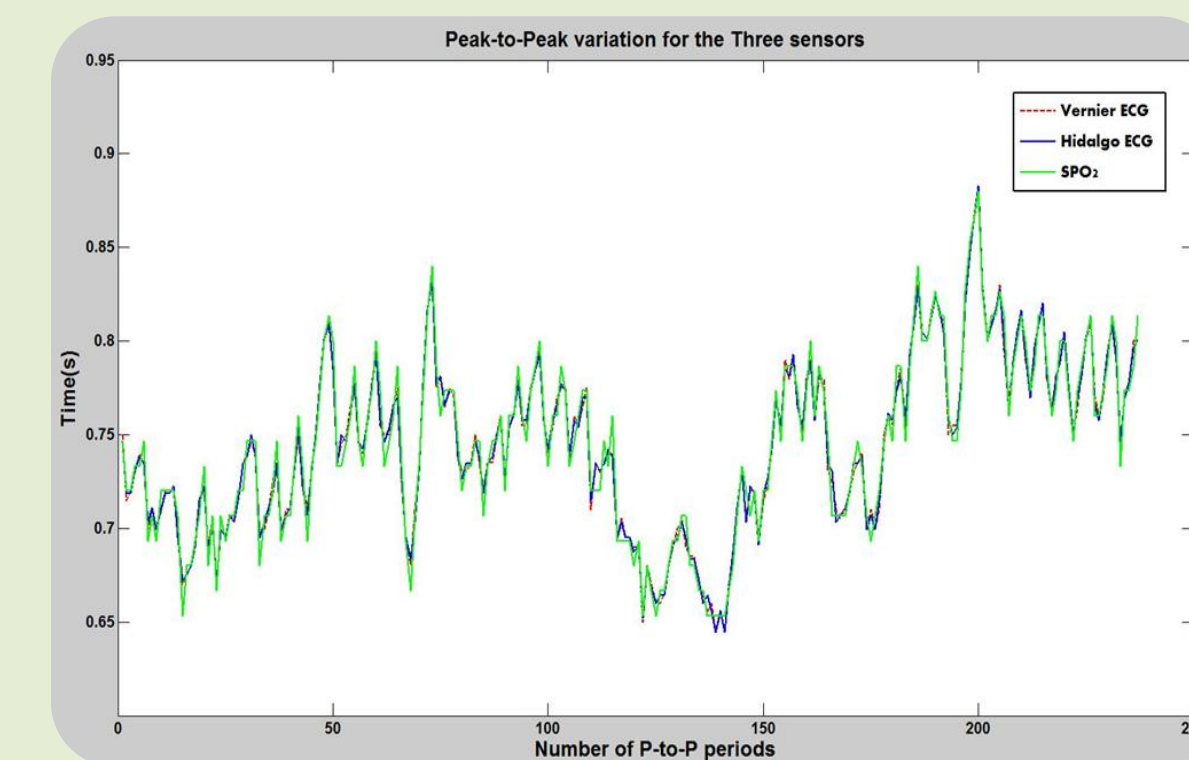
Performance Results

Failure Detection

- Simultaneous Data Recording
- Identify Inconsistencies based of average

Single User

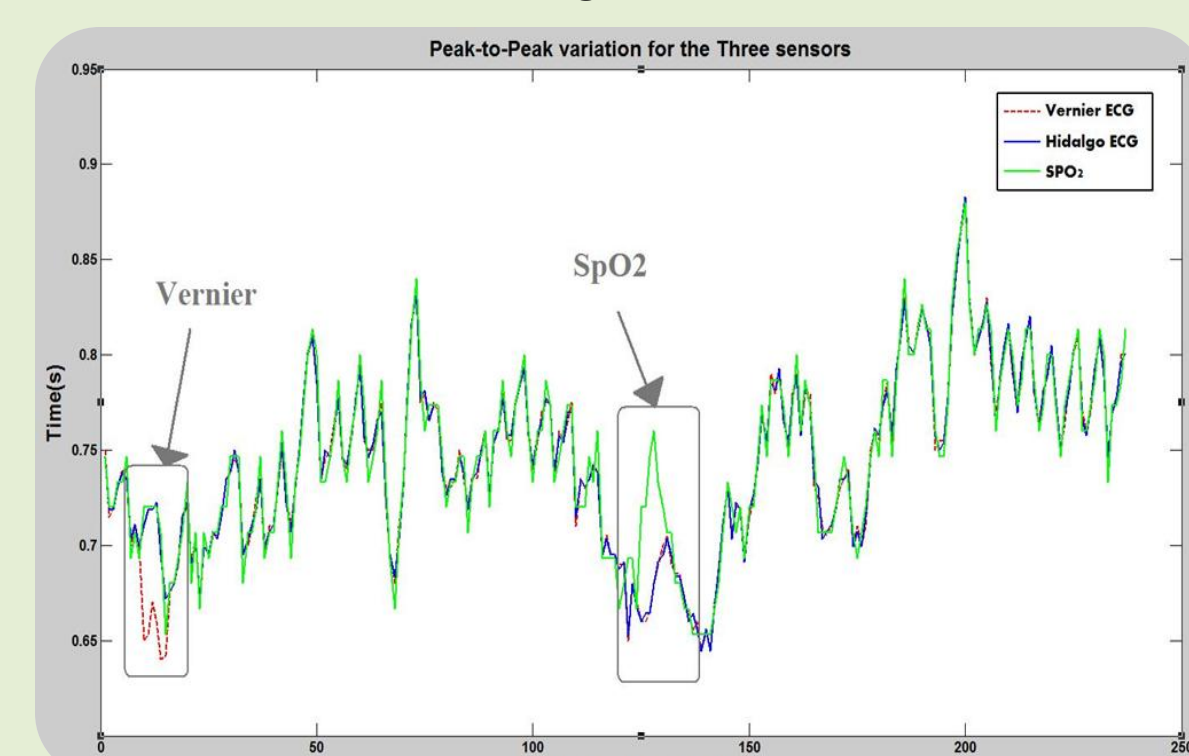
- Hidalgo signal is reference
- Calculate Mean of the difference
- Choose a % allowance
- Identify % Error for each device



Peak to Peak periods of the three devices from a single user

Multiple Users

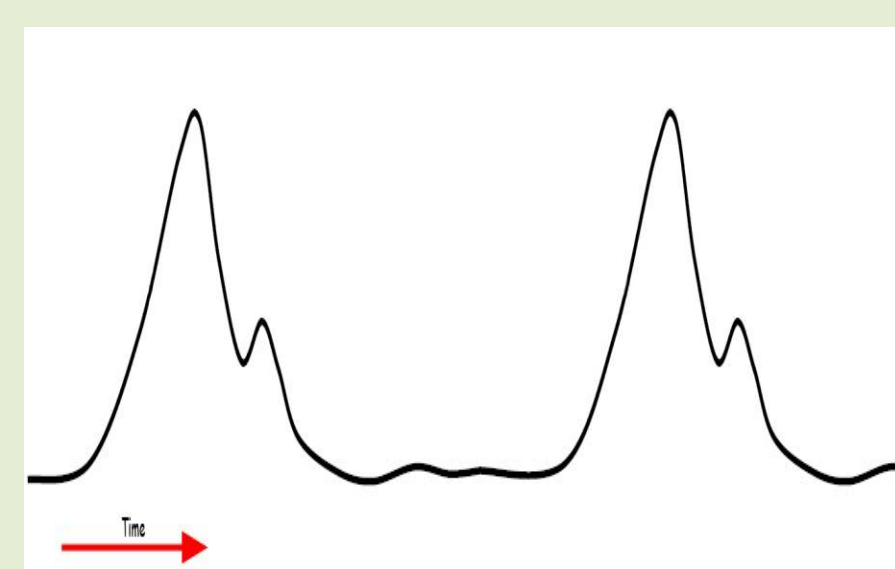
- Replace a set of the Vernier and SpO₂ data from User#1 into User#2
- Detect pulse cycle inconsistencies



Testing Robustness of Error Detection code with multiple user data

Peak Detection

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



Peak Detection

- Iterative Local Maxima algorithm
 - Scan window iterates and extracts the index and amplitude of peak
- Output:
 - P-P periods

