Theme 2

Context Aware Sensor Systems, Software and Applications

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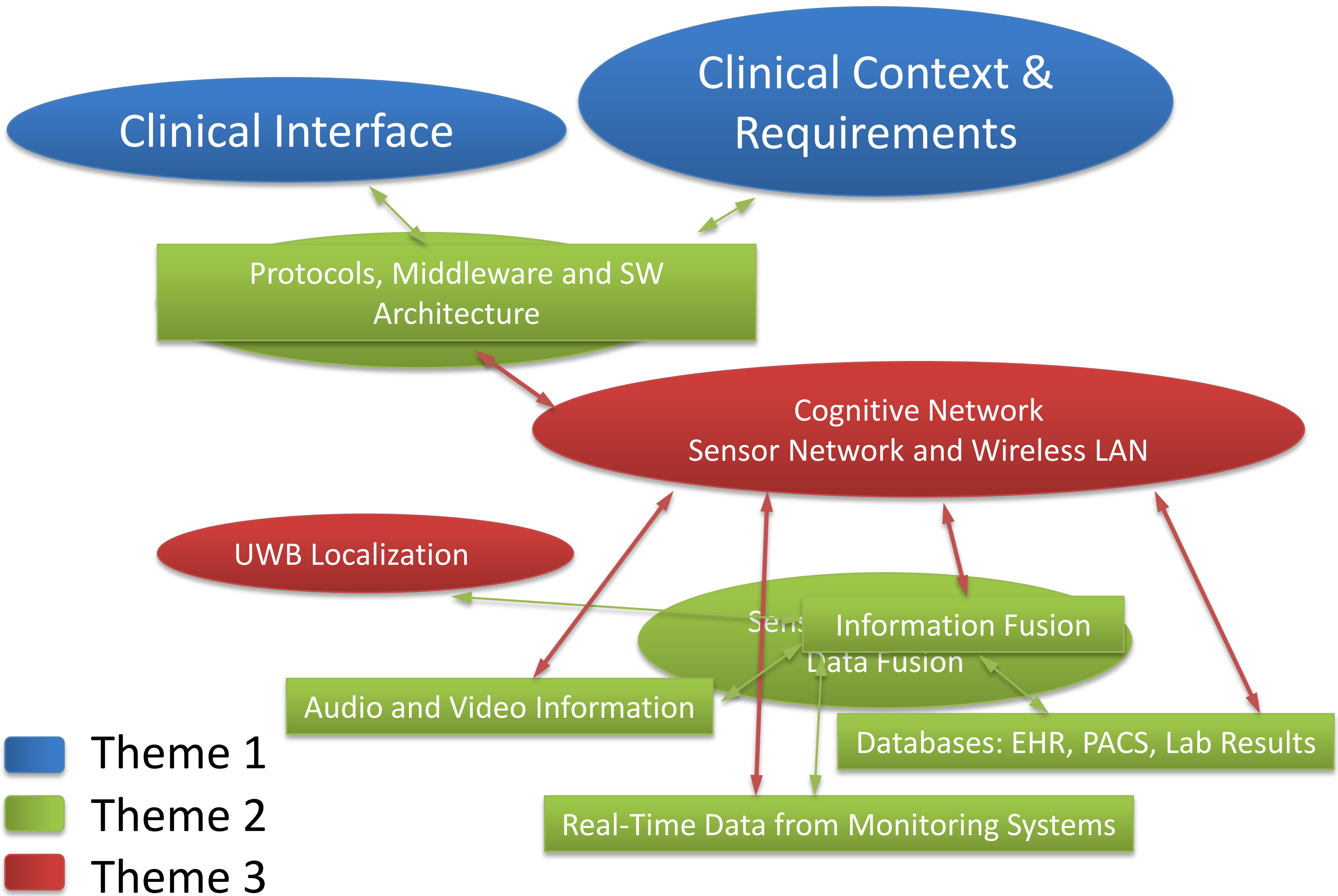
Theme 2 Overview



Main Objectives and Theme Structure

- **Theme 2 conducts research into smart sensor systems that are designed to support context awareness and that will be integrated into the system architecture defined in Theme 1. It's main objective is to design:**
  - software architectures, middleware, supporting software, and protocols
  - signal processing, sensor fusion, and decision support systems

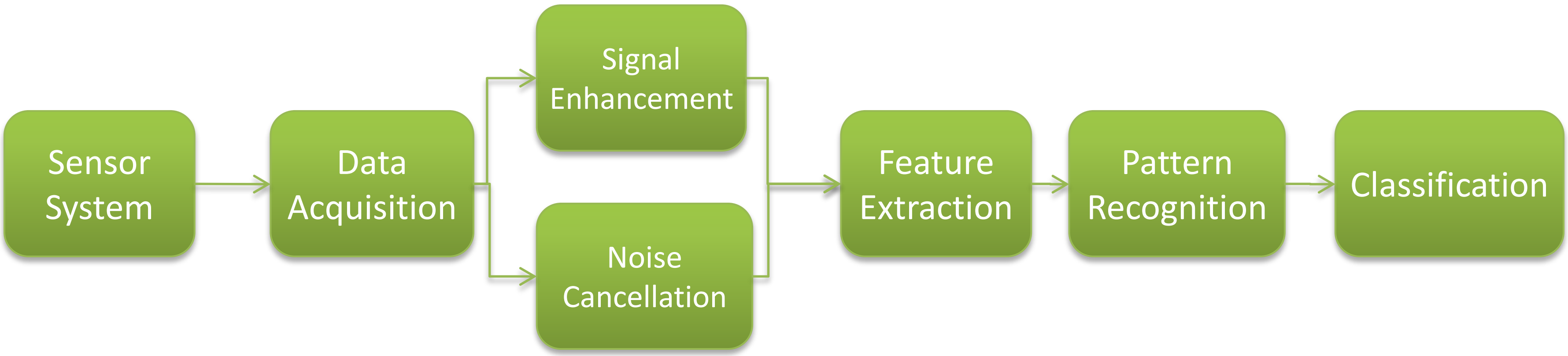
  capable of meeting the stringent requirements of the hSITE application in terms of reliability, context awareness, and fast-response-time

- **Theme 2 is structured around 6 complementary research projects:**
  - Software Architectures, Performance, and Dependability (D. Petriu)
  - Middleware, Protocols, and Supporting Software (P. Liu)
  - Graceful Degradation Compression and Scalable Coding (F. Labeau)
  - Smart Sensors Systems and Data Processing (R. Goubran)
  - Context Aware Multi-Modal Data Fusion (E. Petriu)
  - Clinical Requirements and Assessment (F. Knoefel)

Smart Sensor Systems and Data Processing

Rafik Goubran and Frank Knoefel

- Sensor Information Acquisition and Feature Extraction:
  to extract relevant clinical information from continuous streams of data



- Context aware processing and classification
- Two applications were used as case studies:
  - Audio classification using microphone arrays and/or smart phones (BlackBerry)
  - Clinical feature classification using pressure sensitive sensor arrays

Smart Apartment (Elisabeth Bruyère Hospital)




Clinical Testing

Technology Assessment

Sensor examples

- Simple sensors to localize occupants and monitor home status:
  - IR, ultra sound, magnetic switches, temperature sensors, RFID,

- More complex sensor systems to extract clinical information:
  - **microphone arrays to track sounds (help, cough, snoring, ...)**
  - **pressure sensitive mats to monitor bed occupancy, sleeping quality, breathing, bed exit-entry routines, …**
  - smart grab bars to monitor bathroom activities
  - BT-enabled medication containers for medicine compliance
  - **accelerometers to detect falls** – electronic noses to detect smells
  - telemedicine (eHealth) station and remote interaction with nurses
  - arrays of wireless temperature, humidity, and light sensors
  - thermal camera to detect burners status – **electricity usage monitoring**

Cough Detection and Classification

Cough database — Data Acquisition — Pre-processing — Feature Extraction — Classification

Pre-processing

- Basic segmentation
  - •Std-deviation
  - •STE

Feature Extraction

- Cough length
- •Total Energy
- •STFT
- •Max Power
- •Amplitude
- •No. of peaks
- •MFCC, LPC

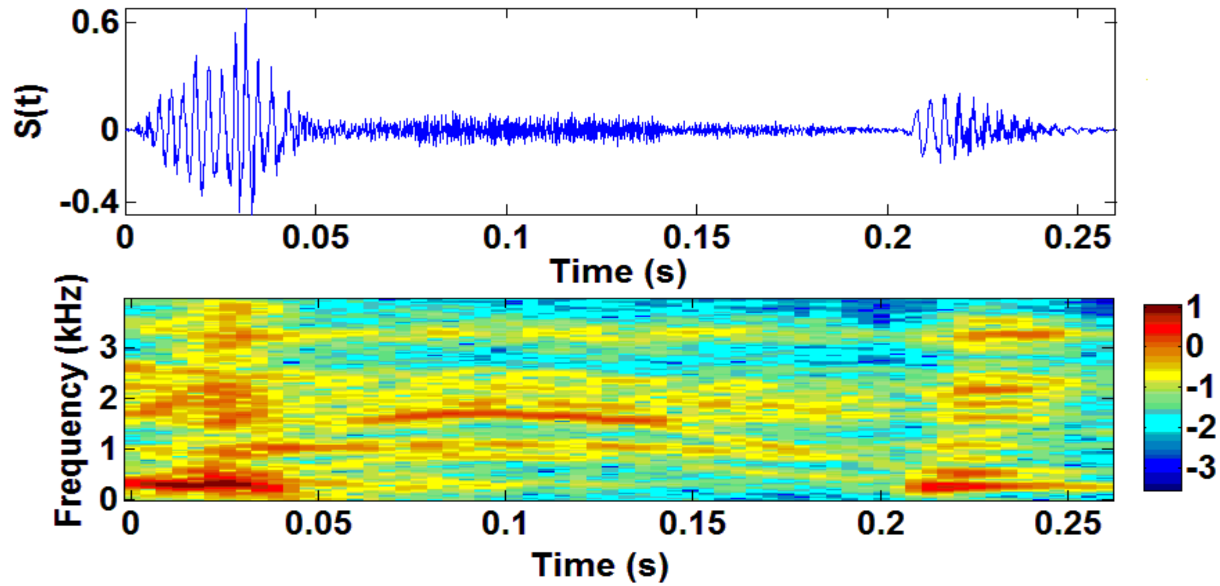
Classification

- •HMM
- •SVM
- •Decision Tree
- •ANN

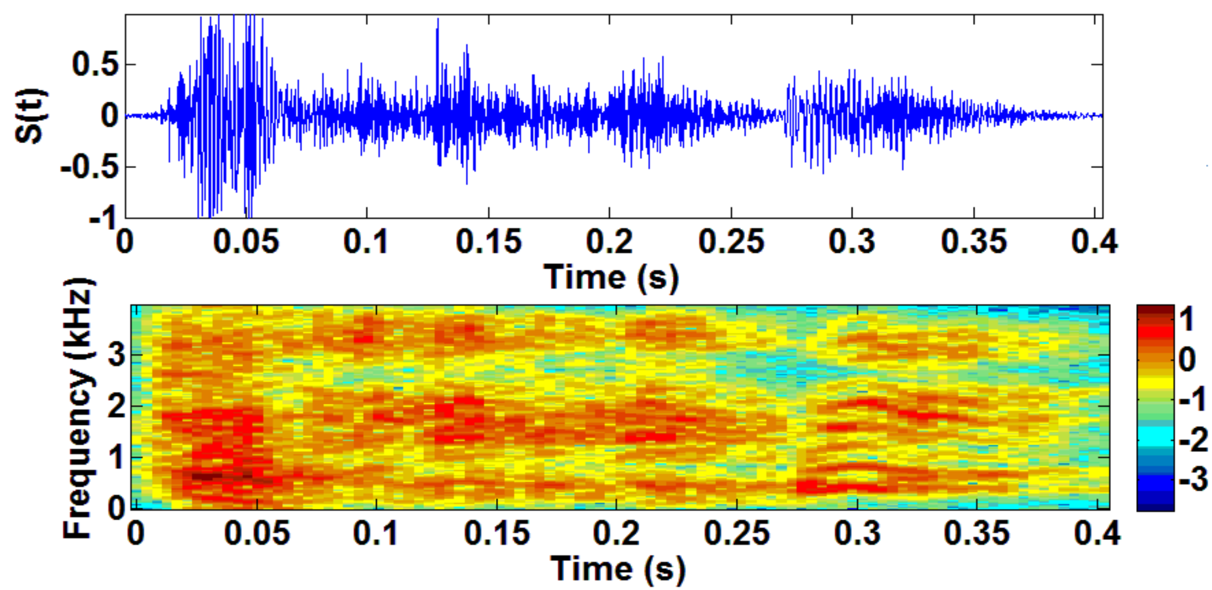
Comparing the outcome of the classifiers

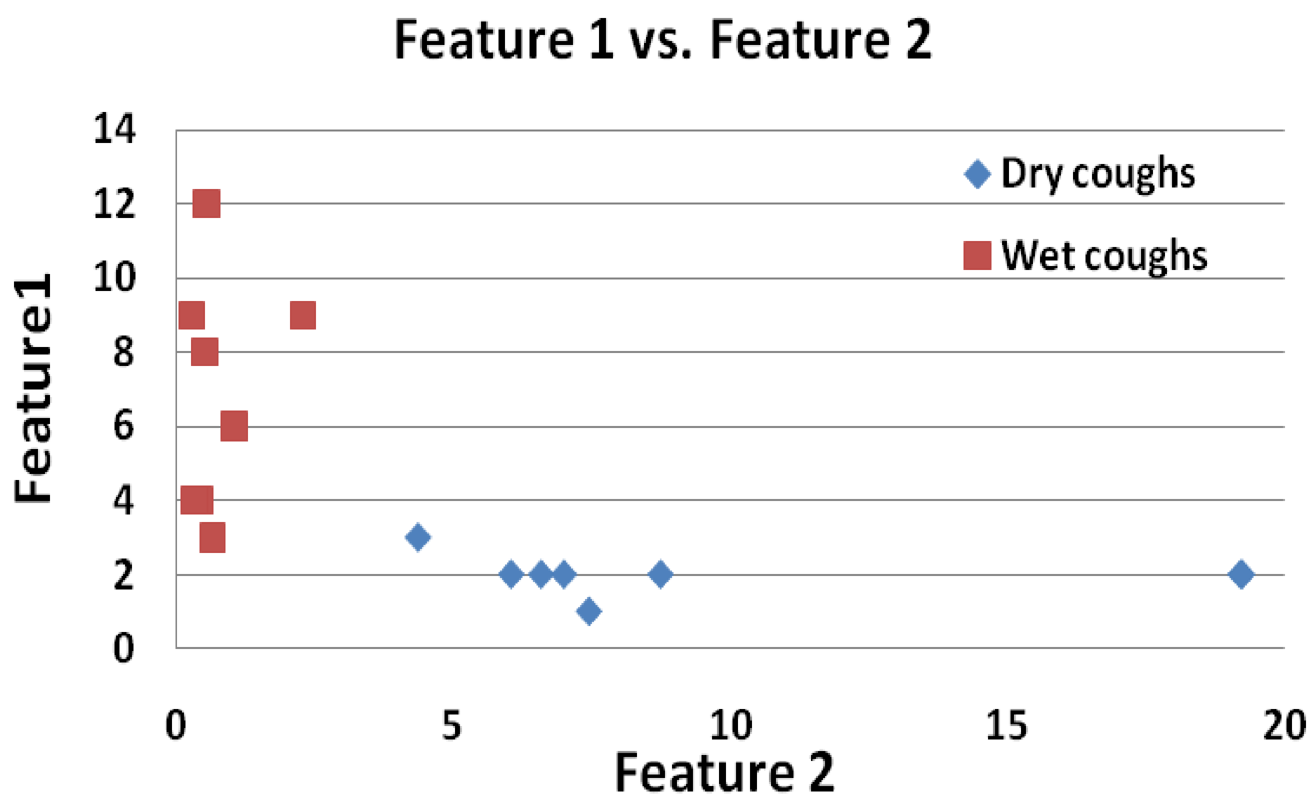
- •Accuracy vs. # of features
- •Recognition rate vs. SNR (Noise, sounds similar to cough sound)
- •Error rate
- •Reverberation

Dry Cough



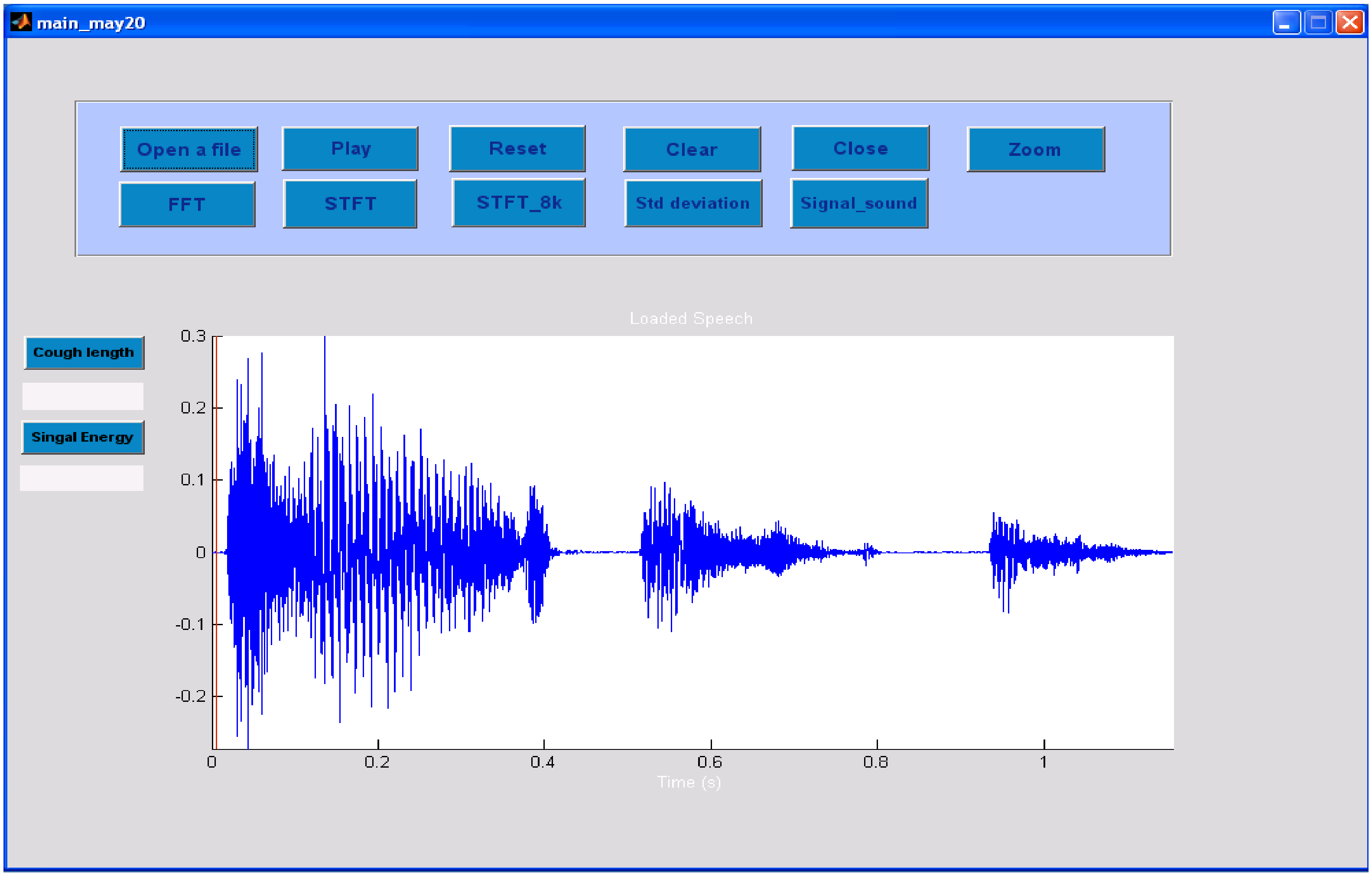
Wet Cough



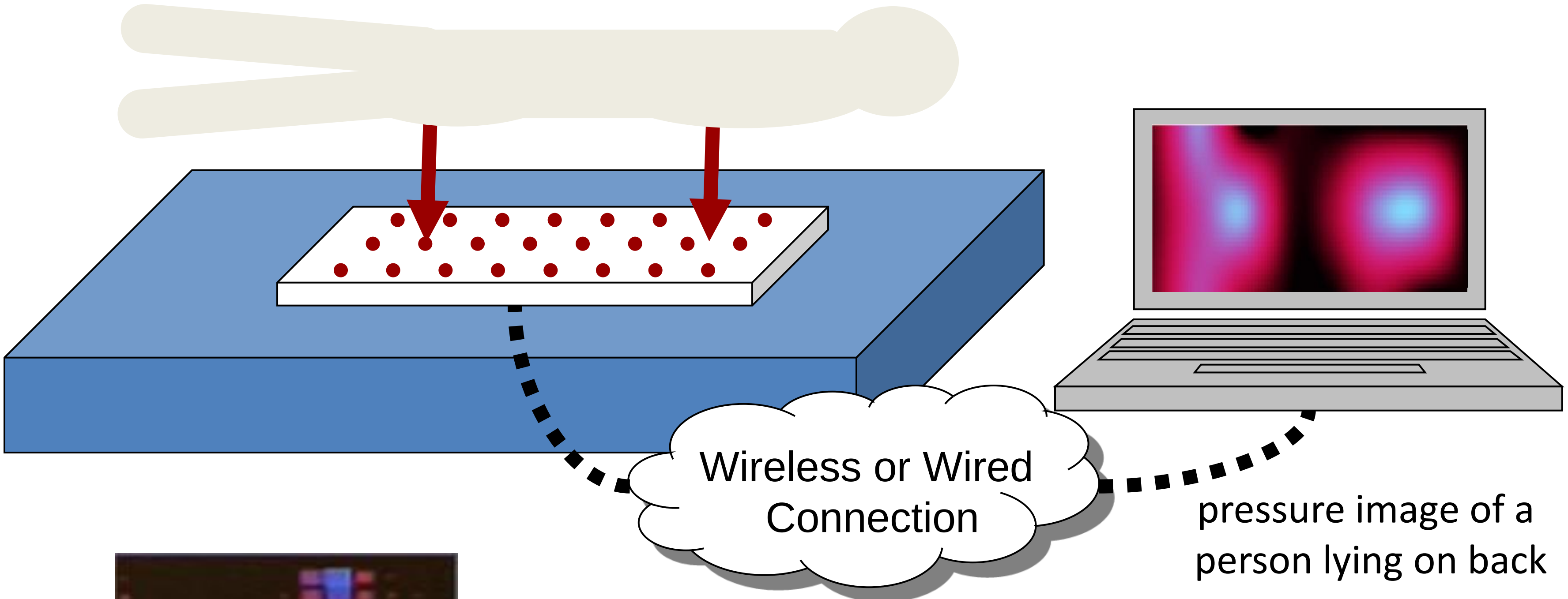


Feature 1 vs. Feature 2
Feature1
Feature 2
14
12
10
8
6
4
2
0
0
5
10
15
20
Dry coughs
Wet coughs

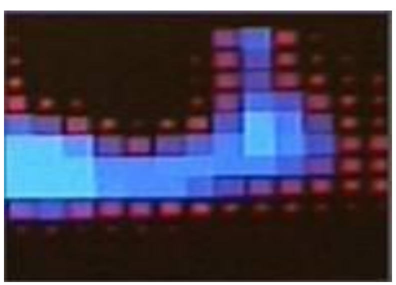
GUI Interface



Pressure Sensitive Mats



pressure image of a
person lying on back

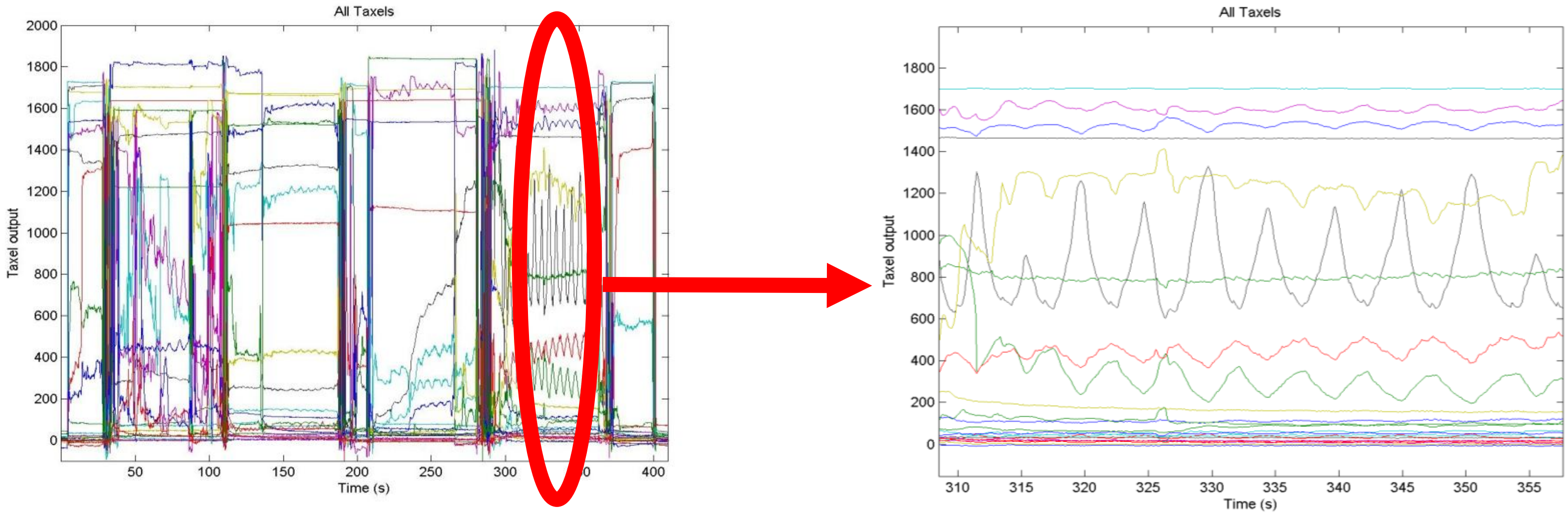


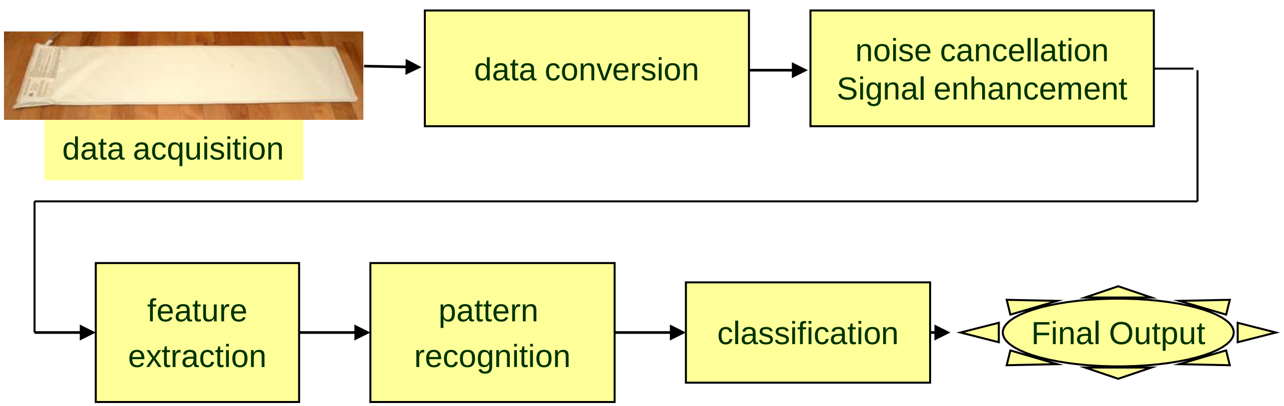
pressure image
of a person lying on side

Data analysis can extract:

- bed occupancy
- movement and activity level
- position and posture; bed entry/exit
- breathing rate and possibly heart rate

Processing Pressure Pad Data



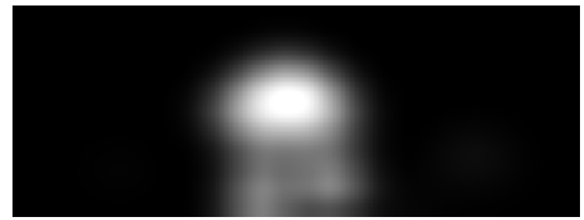


adjust sleeping and
pain killer medication
according to sleep quality

Sit to Stand Analysis

Sample sit-to-stand sequence images

Timing – Bouncing - Symmetry

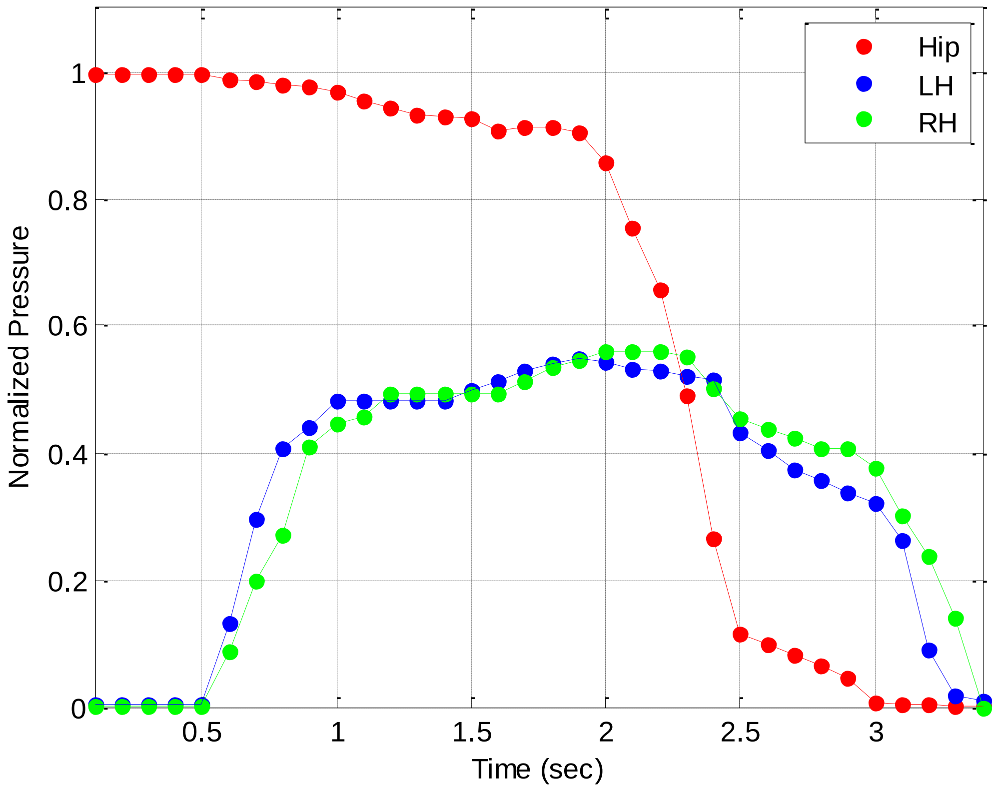


Hip pressure region

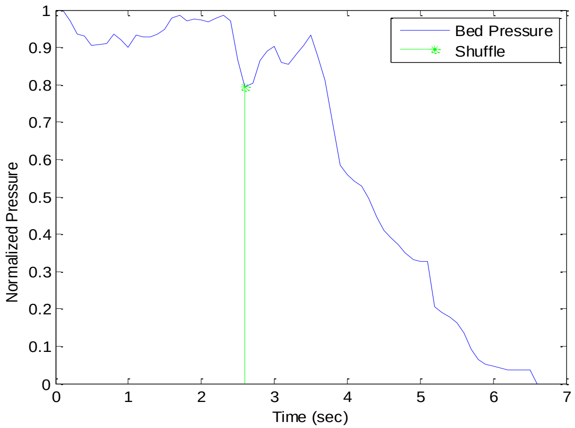
Hip and hand pressure regions

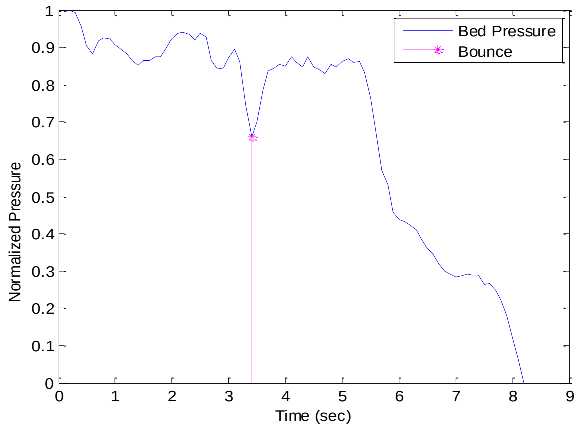
Hand pressure regions

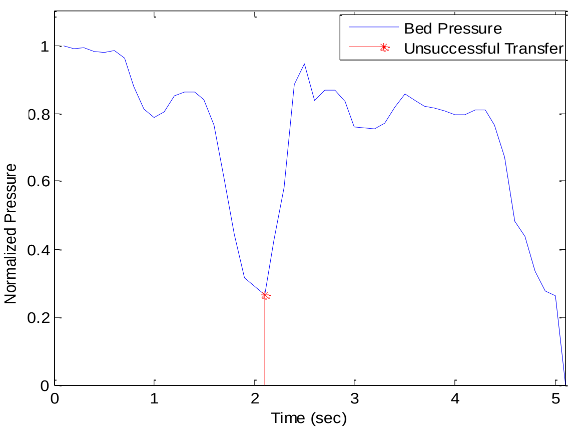
Ideal Sit-to-Stand Transfer From Control Participant



Bounce Detection Algorithm





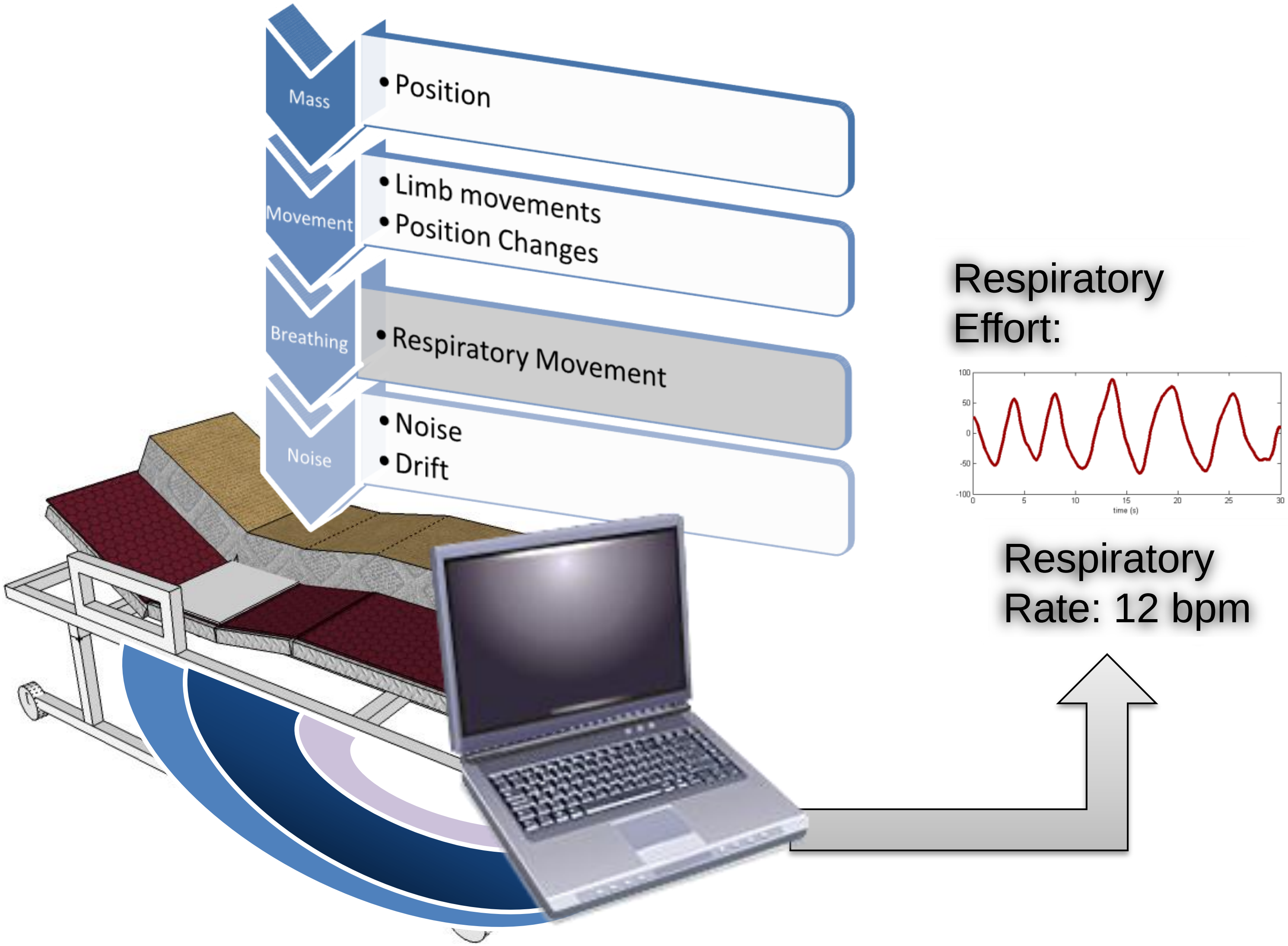


1. Shuffling in the sit position

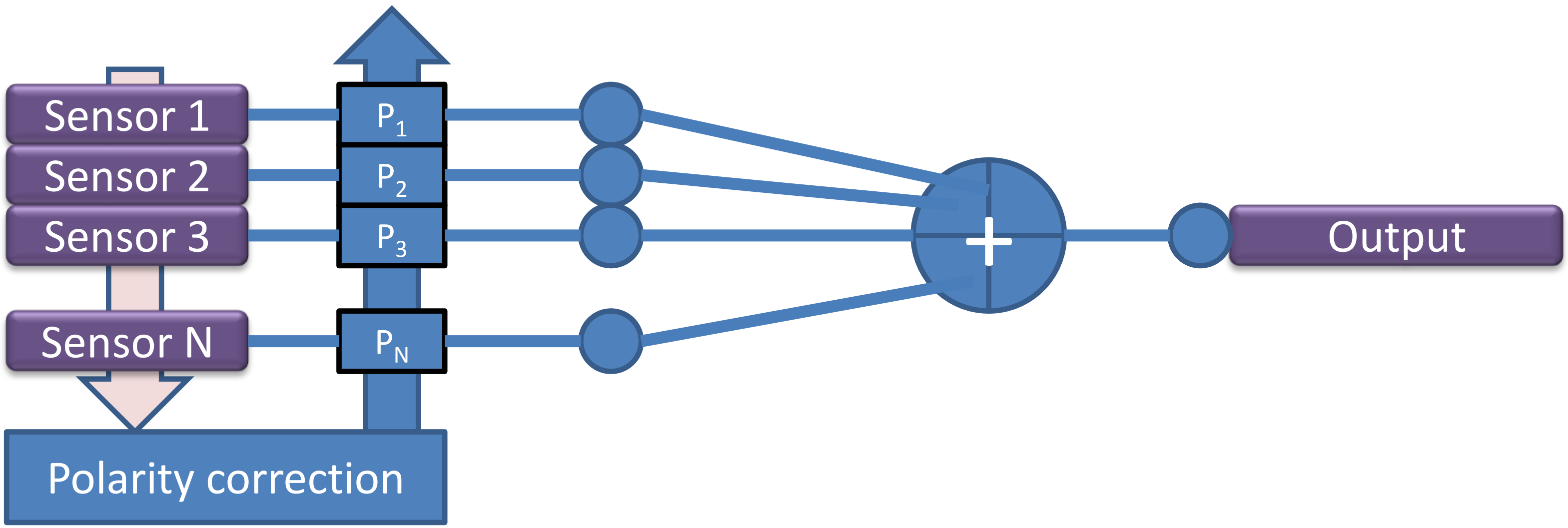
2. Bouncing to generate momentum before standing up

3. Unsuccessful transfer

Time-Varying Pressure Signals for Respiratory Effort Extraction

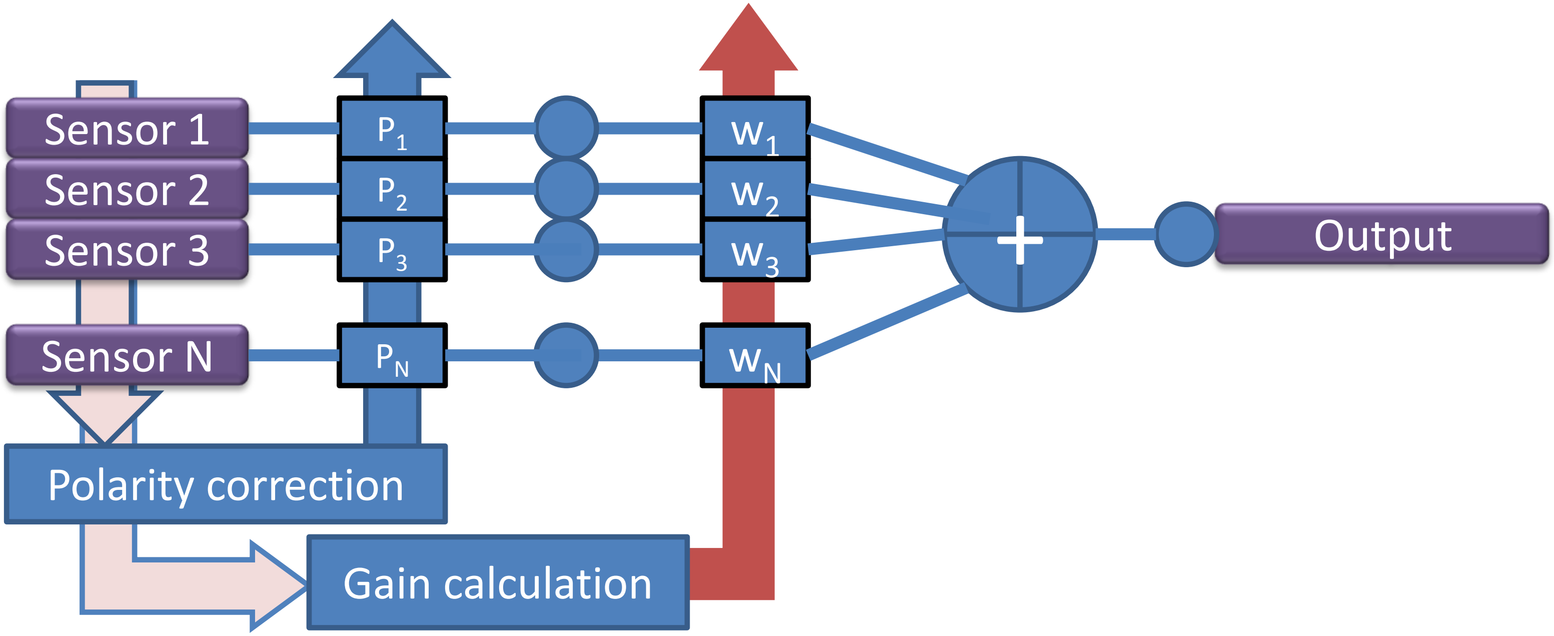


Equal Gain Combiner



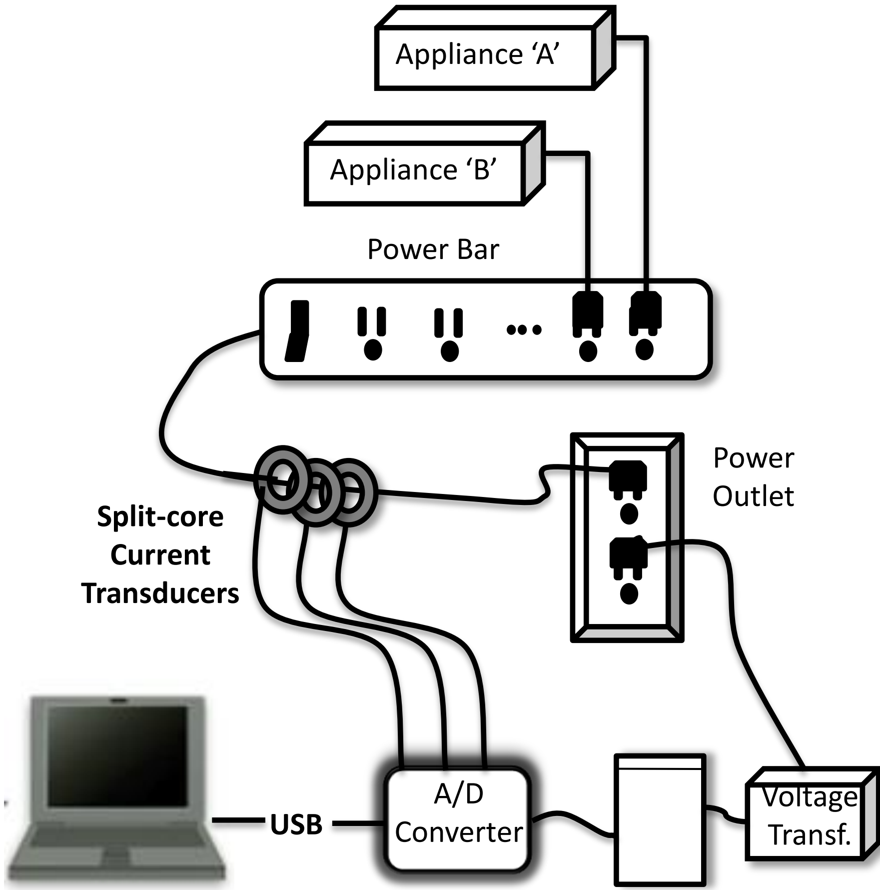
- All signals are combined by simple summation
- Signals must be coherent
  - During inhalation, shifts in the centre of pressure cause increased pressure on some sensors while others are unloaded
  - Adding signals with opposite polarities would cause destructive interference
    - Polarity correction is applied to reverse signals travelling in opposite directions

Proposed Combiner



- Each sensor is multiplied by an individual weight factor (gain)
- Weights are proportional to square root of signal power and inversely proportional to total noise power

Non-Intrusive Appliance Use Monitoring



Electrical devices used in experimental setup, along with their mean RMS current and reactive power (± standard deviation), computed across all measurements.

Load	Devices	RMS Current (A)	Reactive Power
1	Microwave	7.72 ± 0.21	64.71 ± 26.04
2	Electric kettle	7.34 ± 0.04	90.77 ± 1.61
3	Coffee maker	5.56 ± 0.03	66.06 ± 1.16
4	Laptop charger	0.80 ± 0.23	38.77 ± 10.05
5	Incandescent lamp	0.53 ± 0.01	9.18 ± 0.16
6	Computer & LCD	0.41 ± 0.01	29.91 ± 14.11
7	Fluorescent lamp	0.28 ± 0.03	18.66 ± 1.99

Context Aware Multimodal Information Fusion