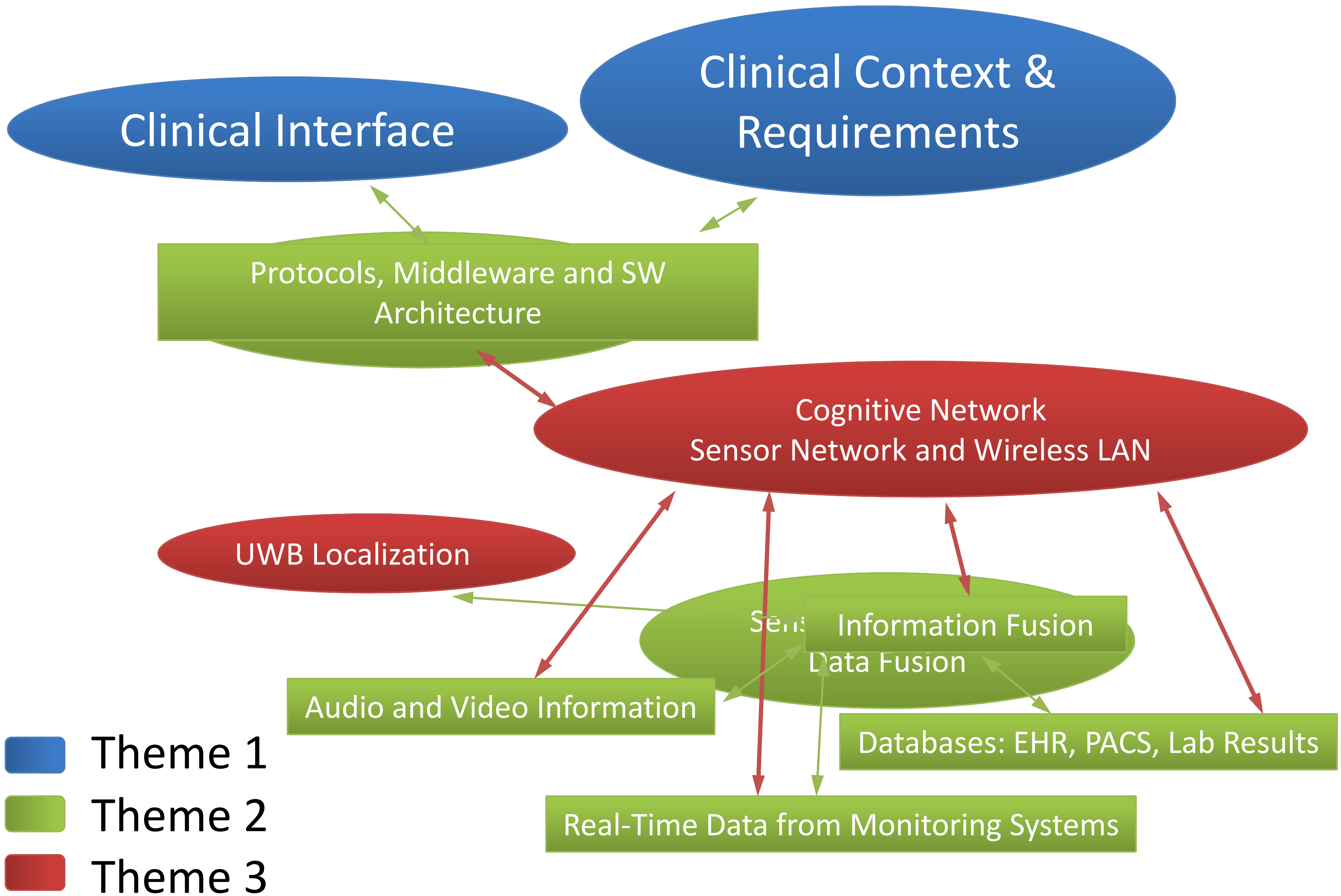
Theme 2

Context Aware Sensor Systems, Software and Applications

Theme Leader: Rafik Goubran

Dorina Petriu, Peter Liu, Frank Knoefel, Emil Petriu, Fabrice Labeau

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

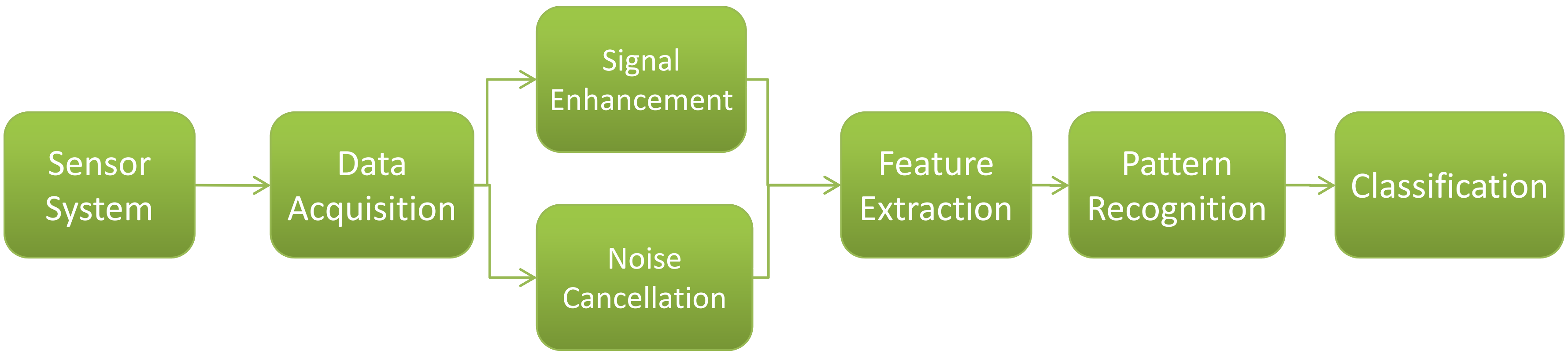
  capable of meeting the stringent requirements of the hSITE application in terms of reliability, context awareness, and fast-response-time

- **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

Design Assumptions and Criteria

Users likely suffer from some weaknesses or impairments

(e.g. reduced mobility, slower response time, cognitive limitations, visual or hearing impairments, …)

proper user interfaces and ergonomic design are vital

- minimize user intervention (ideally no intervention at all)
- minimize invasion (e.g. no cameras, especially PTZ)
- smartness has to be transparent to the user and should not impact the environment

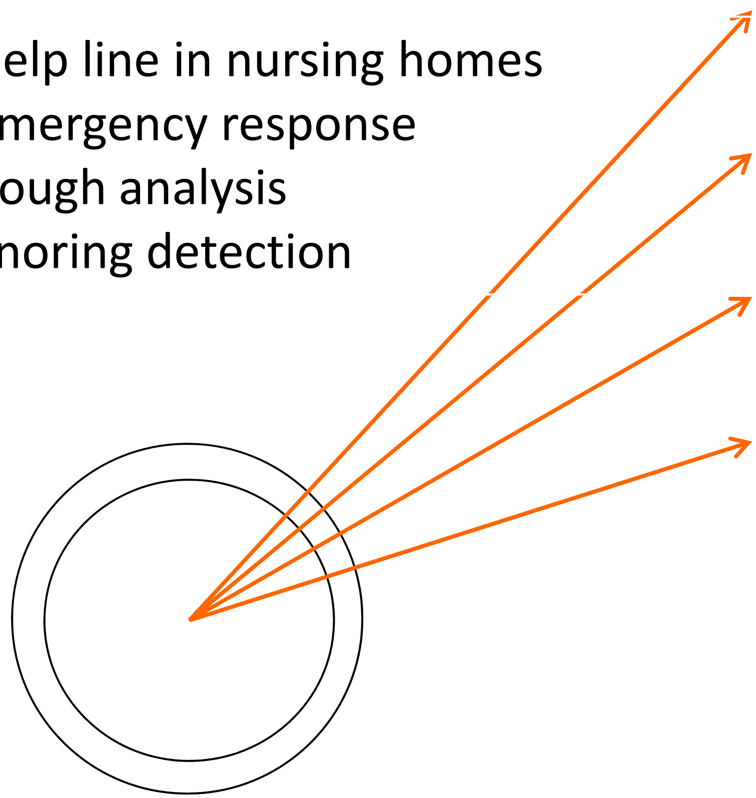
Sensor examples

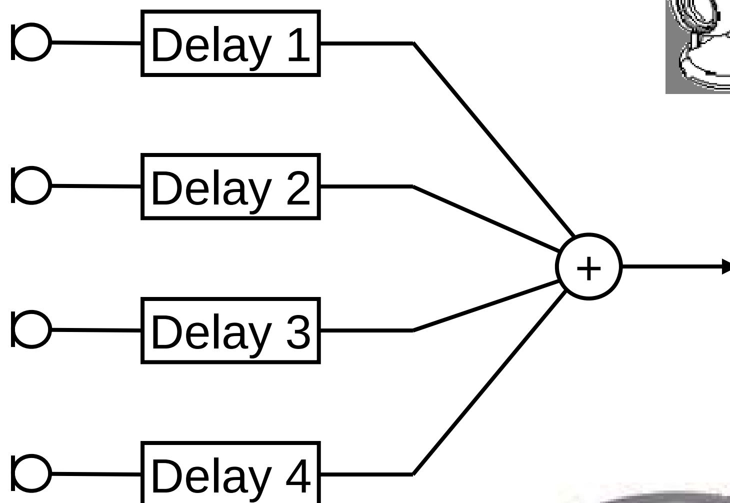
- Simple sensors to localize occupants and monitor home status:
  - IR, ultra sound, magnetic switches, temperature sensors, RFID,

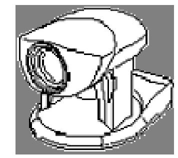
- More complex sensor systems to extract clinical information:
  - microphone arrays to track sounds (help, cough, snoring, ...)
  - pressure sensitive mats to monitor bed occupancy, sleeping quality, breathing, bed exit-entry routines, …
  - smart grab bars to monitor bathroom activities
  - BT-enabled 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

Sound Localization using Microphone Arrays and Near-Field Beam-Forming

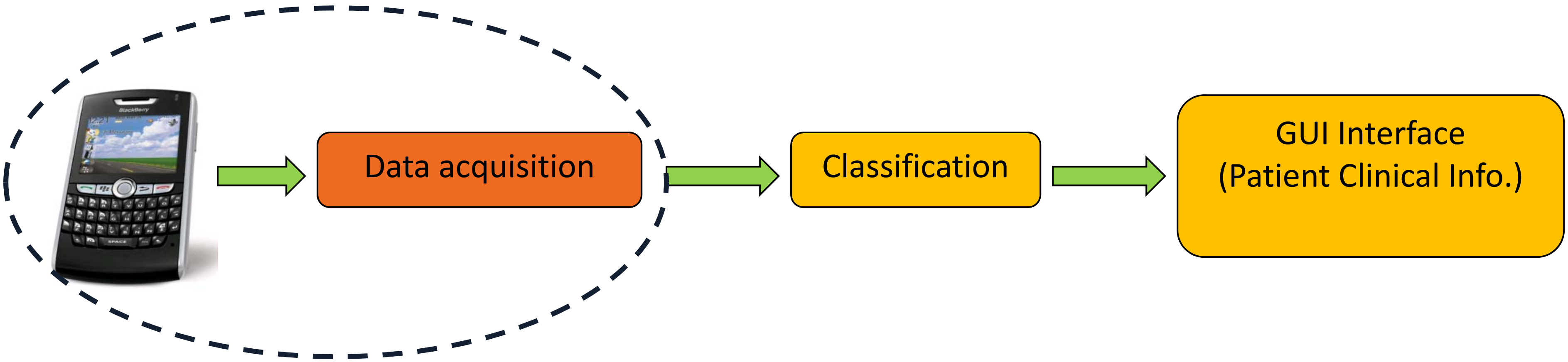
- Help line in nursing homes
- Emergency response
- Cough analysis
- Snoring detection



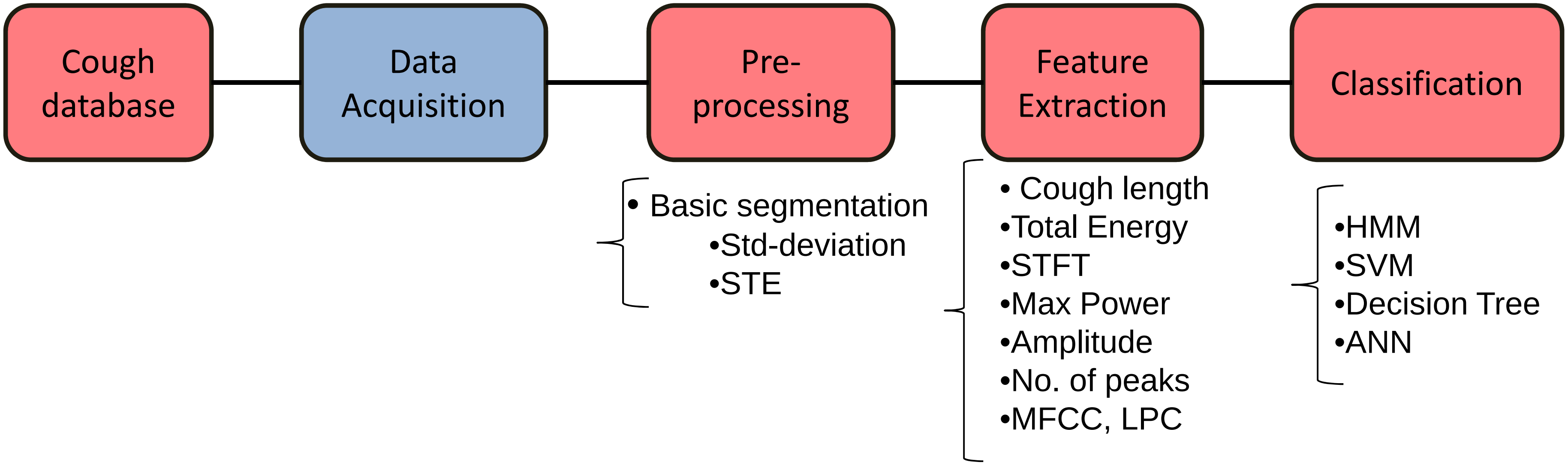




Audio Analysis using Smart Phones



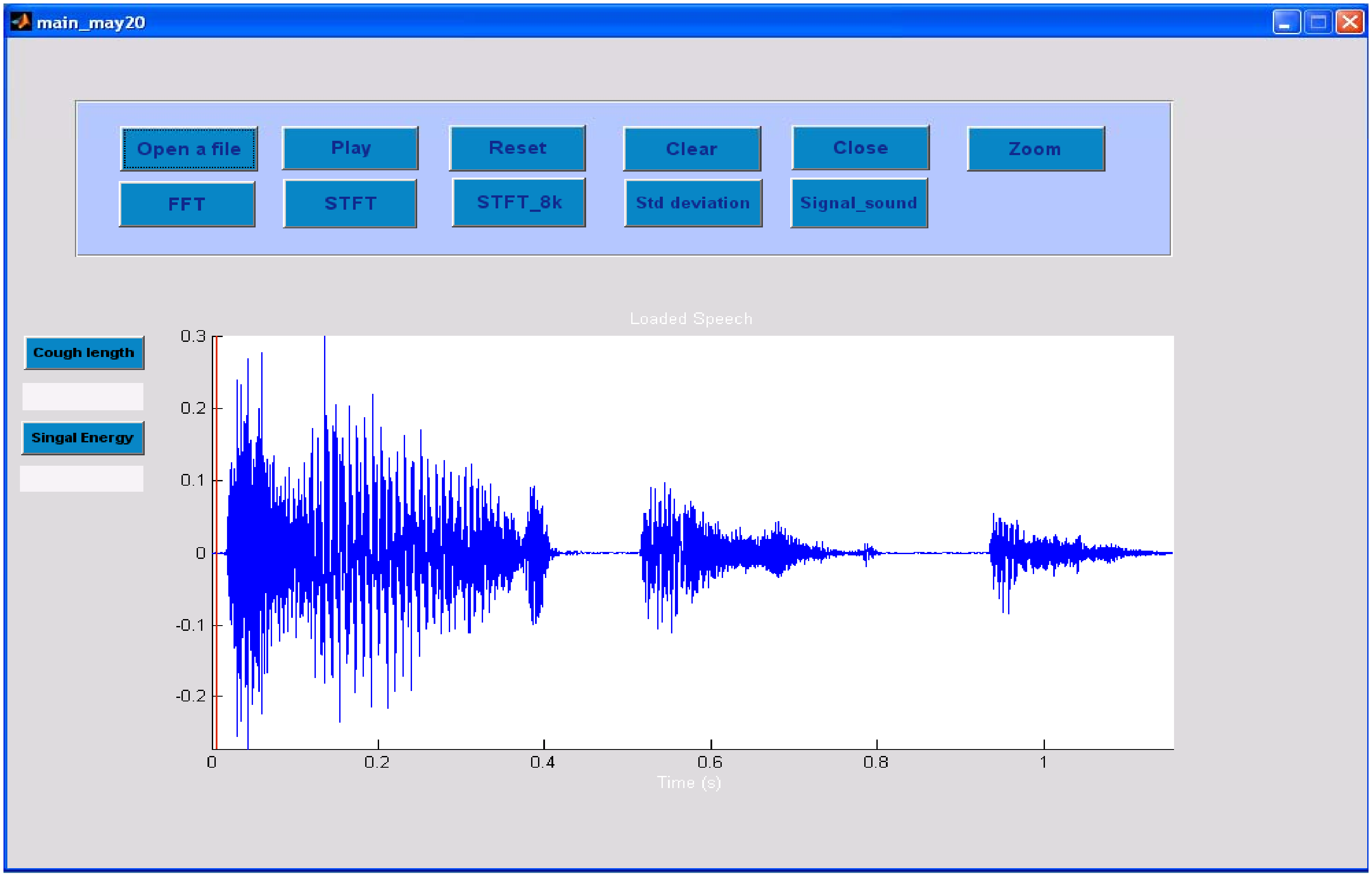
- Signal enhancement
- Noise cancellation
- Acoustic echo cancellation
- Beam-forming algorithm
- Microphone array structure
    - # of microphones
    - Spacing
    - Array configuration



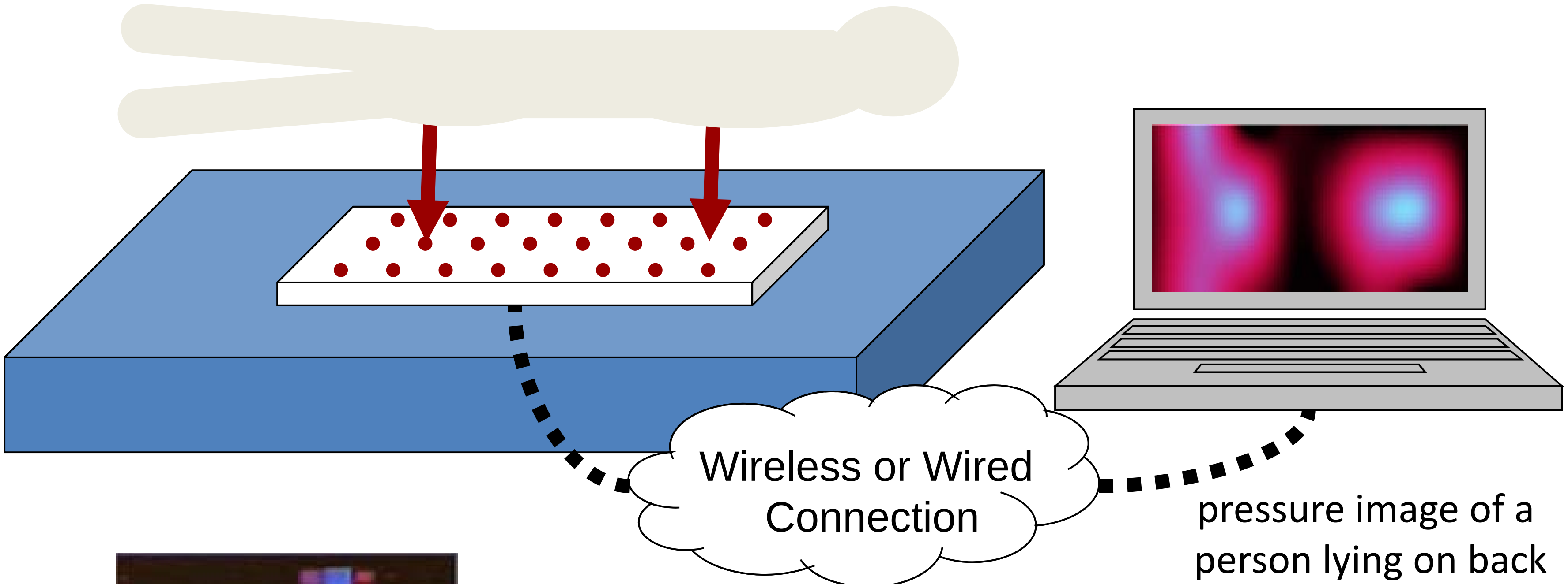
Comparing the outcome of the classifiers

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

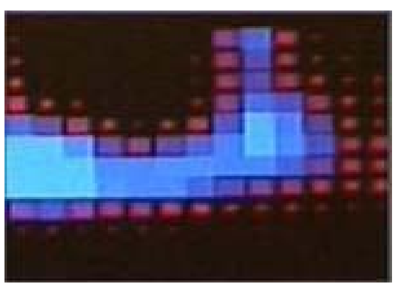
GUI Interface



Pressure Sensitive Mats



pressure image of a person lying on back

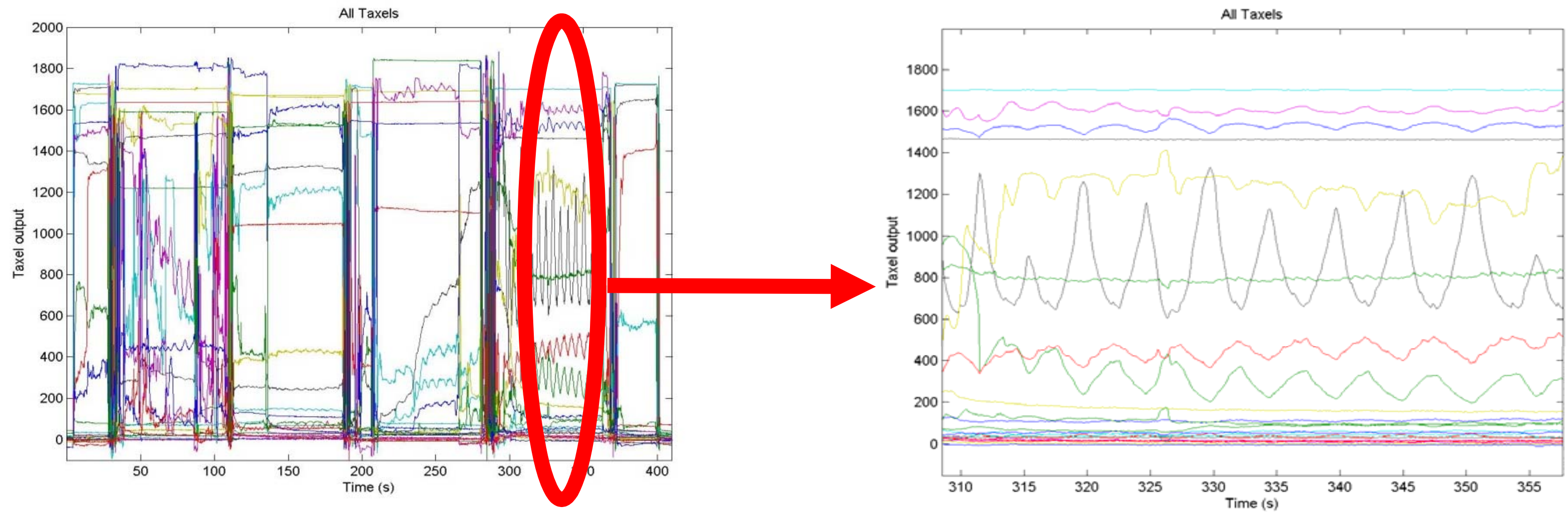


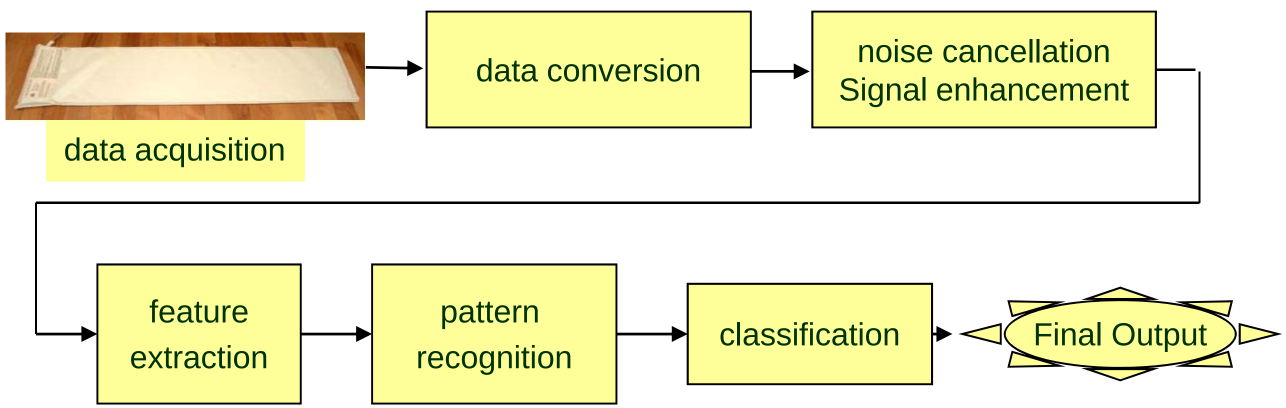
pressure image
of a person lying on side

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



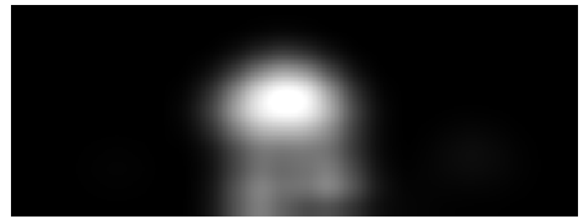


adjust sleeping and
pain killer medication
according to sleep quality

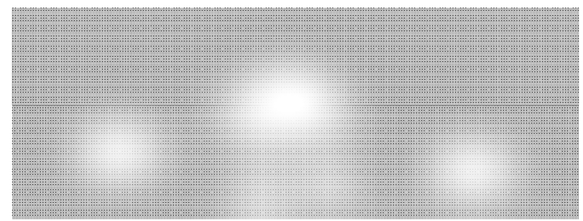
Sit to Stand Analysis

Sample sit-to-stand sequence images

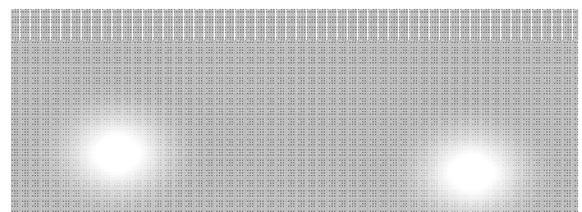
Timing – Bouncing - Symmetry



Hip pressure region

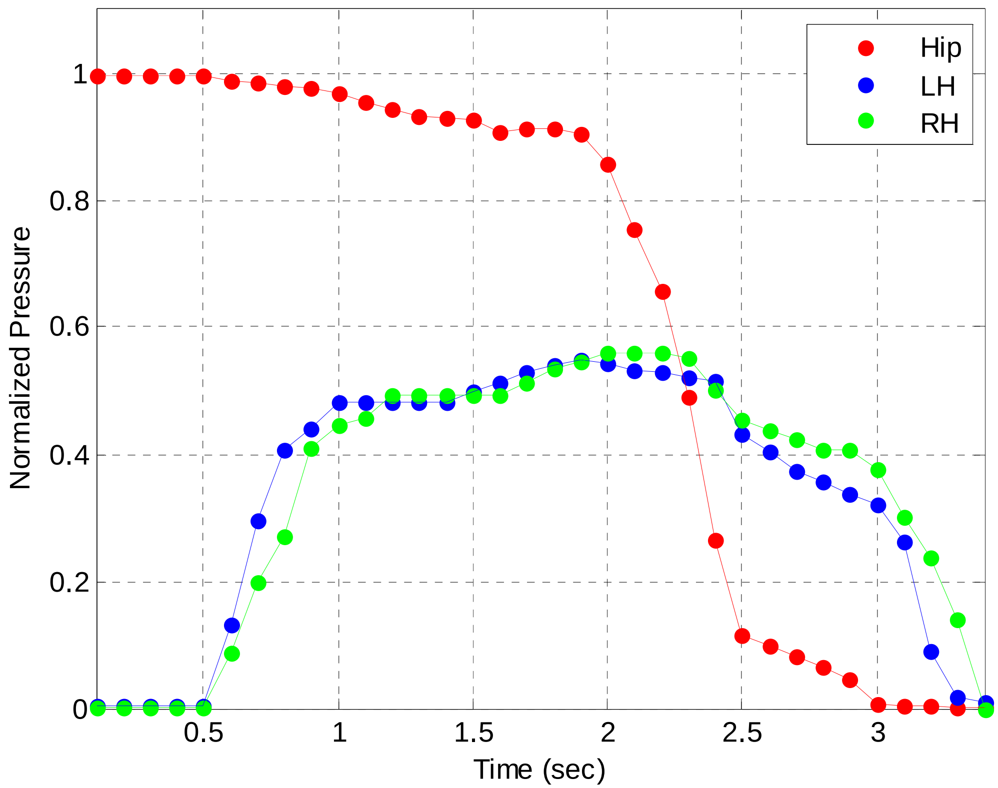


Hip and hand pressure regions

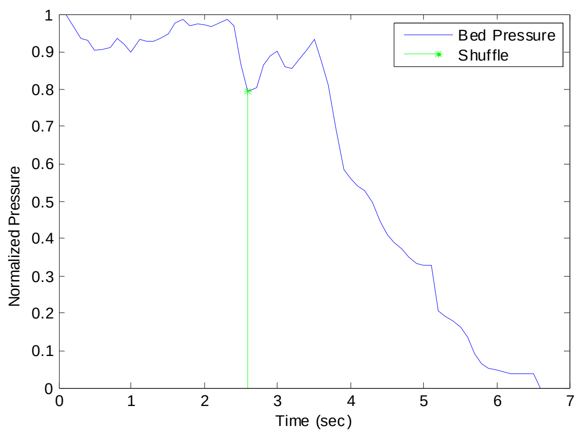


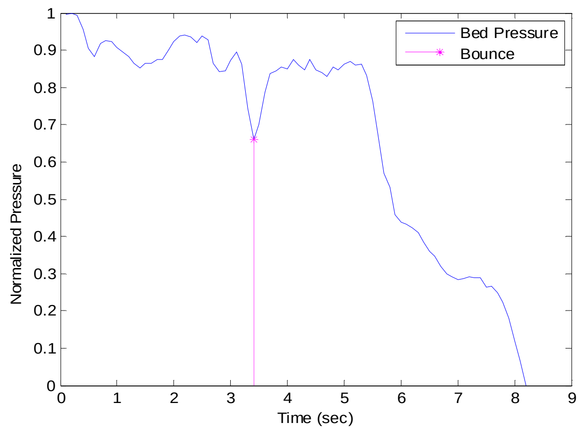
Hand pressure regions

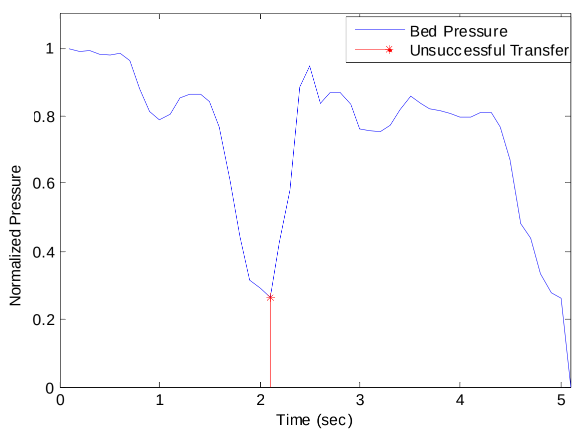
Ideal Sit-to-Stand Transfer From Control Participant



Bounce Detection Algorithm







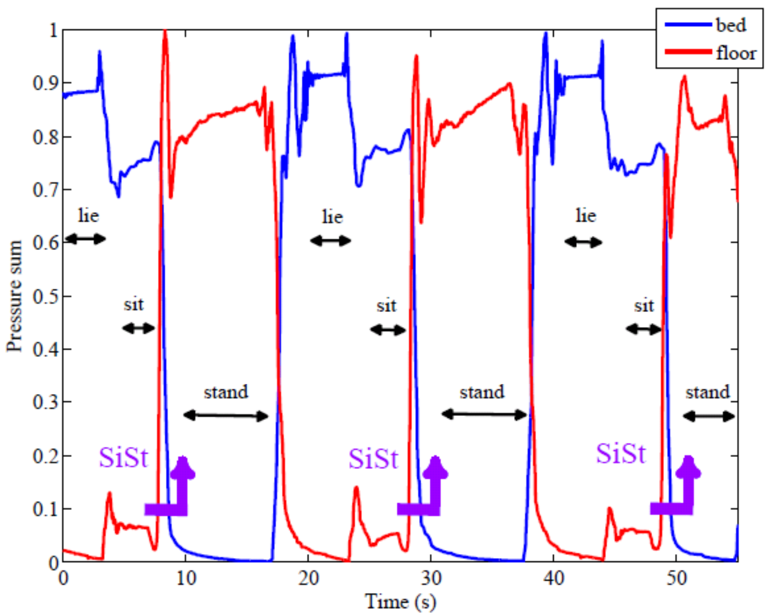
1. Shuffling in the sit position

2. Bouncing to generate momentum before standing up

3. Unsuccessful transfer

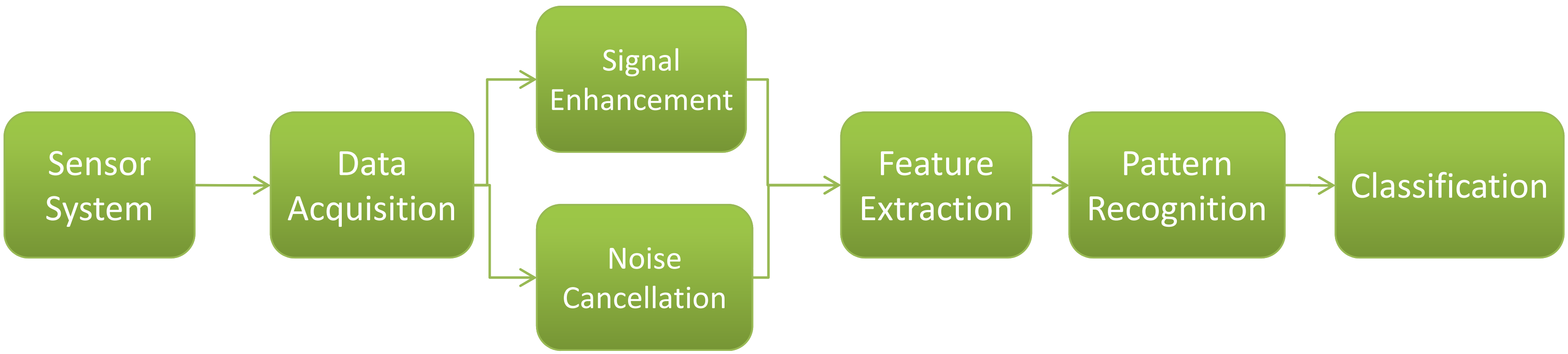
Classification of Mobility
in the Smart Home Environment

a) Measurement of the duration of sit-to-stand transfers using bed and floor pressure sequences



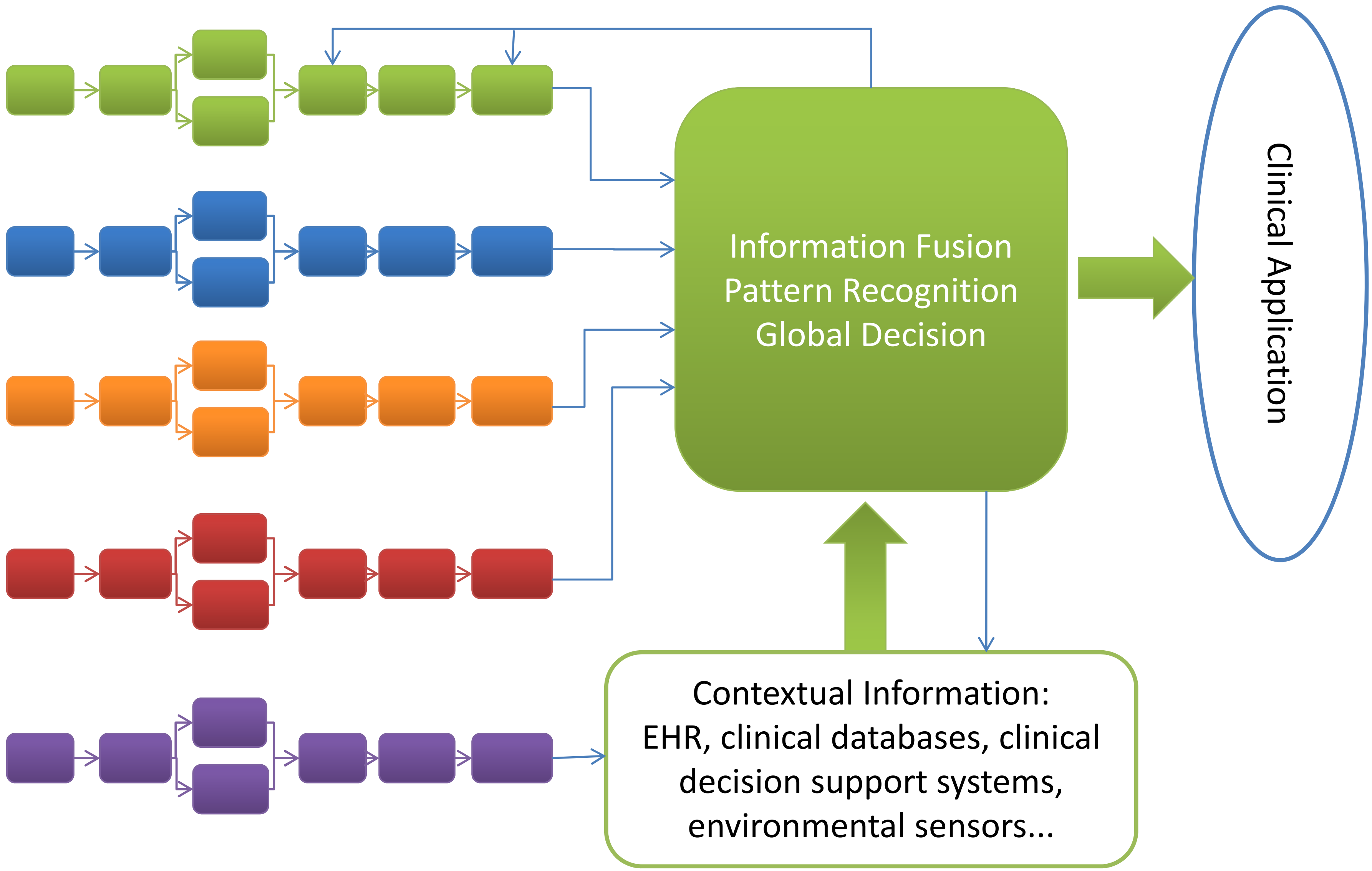
b) Classification of mobility-impaired sit-to-stand transfers based on COP trajectory

Parameter	Healthy	Mobility-Impaired
Sagittal Variance (cm)	0.64	6.52
Seat-Departure Duration (s)	2.8	4.8
Forward Displacement (cm)	5.06	14.20
Transversal Variance (cm)	3.56	18.21



Sensor System
Data Acquisition
Signal Enhancement
Noise Cancellation
Feature Extraction
Pattern Recognition
Classification

Context Aware Multimodal Information Fusion



Smart Sensor Systems and Data Processing

Rafik Goubran

- Proposed appropriate beam-forming and beam-steering approaches that can capture sounds from any desired location and analyze them.
  - Based on BlackBerry smart phones or fixed microphone arrays
  - Investigating array architecture, beam forming and beam steering algorithms
  - Case study: capturing cough sounds from patients and extracting relevant clinical information (nature, frequency and severity)
- Processed data from pressure-sensitive mat and design digital signal processing algorithms to extract clinical data from pressure-sensitive mats to monitor sleep quality, bed-entry and bed-exit routines
- Explored other sensor systems that can be used to monitor the health and well-being of patients in the hospital or homecare environment such as temperature sensors, accelerometers and steerable cameras

Clinical Requirements and Assessment

Frank Knoefel

- Identified and characterized relevant clinical information that can be extracted from pressure-sensitive mats that are placed under the bed mattress in a hospital, long-term care facility or smart home
  - sleep quality, sleeping position, weight variations, bed exit symmetry and "bouncing" – multiple attempts to get off the bed
  - Bed transfer data related to participants having recently been affected by strokes and hip injuries were also analyzed.
- Finalized appropriate experiments and data gathering configurations.
  - Identified clinical protocol for gathering the data
  - designed appropriate experiment set-up especially in terms of placement of the mat within the bed and number of mats utilized.
- Investigated clinical usefulness of other sensor systems that are proposed by other hSITE researchers. Examples include temperature sensors, accelerometers and steerable cameras