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ObeSense RTD 2013

FNSNF

Early Classification of Pathological Heartbeats on Wireless Body Sensor Nodes

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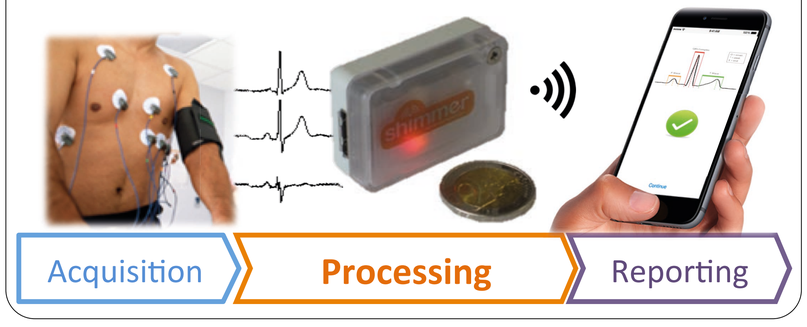
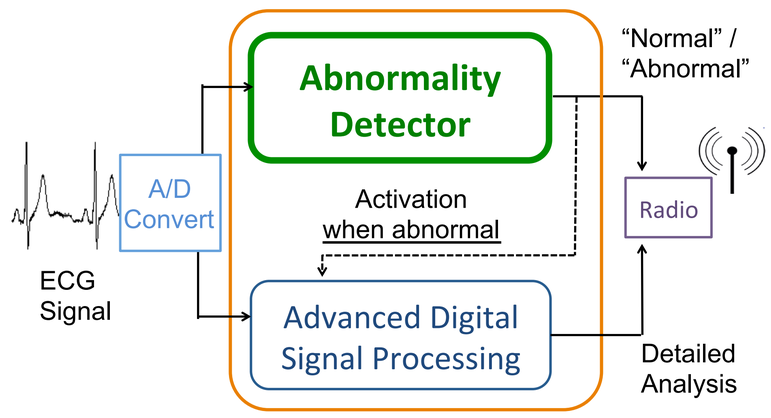
WBSN in Healthcare

- **Wireless Body Sensor Nodes (WBSNs)** are wearable devices used to perform health monitoring (e.g. cardiac monitoring[1])
- **Continuous** advanced Digital Signal Processing (DSP) is typically embedded:
  + Less transmission → Energy Efficiency
  - **Unnecessary** when nothing happens (most of the time!)



PROPOSAL: Selective Advanced DSP

- Detailed analysis is **only** triggered in the presence of **abnormalities**



Necessity of efficient and accurate detector:
Heartbeat Classifier

CHALLENGE: On-node Classification

1. **Prohibitive problem size**
   - Big heartbeat representation
   - Large set of features needed

   → **WBSNs are very resource-constrained**

2. **Complexity of existing alternatives**
   - Based on costly manipulations (e.g. SVMs with Gaussian kernels)

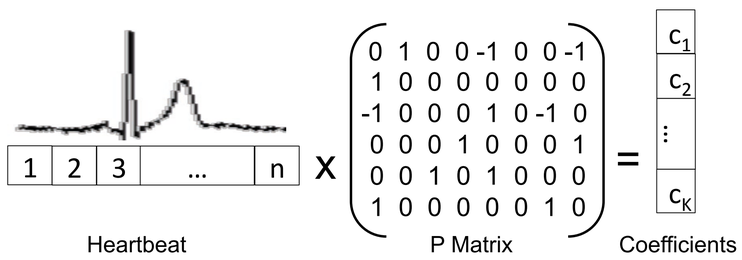
   → **Incompatible with WBSNs**

3. **Training process**
   - Unknown a-priori set of features
   - Tight clinical classification constraints

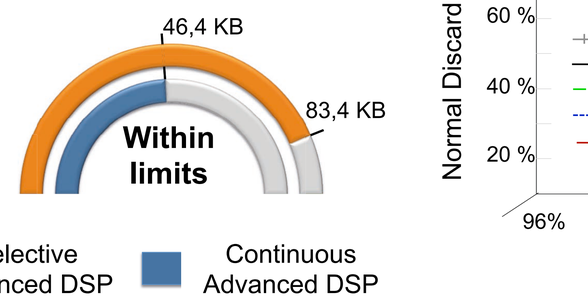
   → **Need for a proper training framework**

OUR STRATEGY: Heartbeat Neuro-Fuzzy Classifier for WBSNs

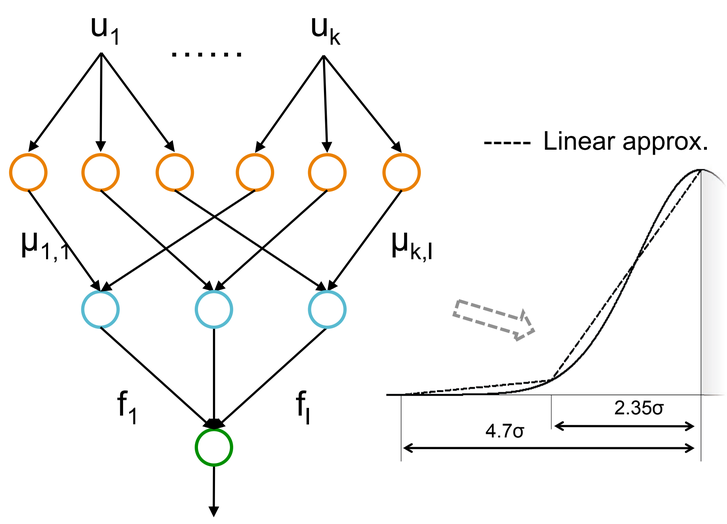
1. **Dimensionality Reduction**
   - Random Projection[2] (RP) of heartbeat provides a reduced set of coefficients



   - Principal Component Analysis[3] (PCA)
   - Signal down-sampling
   - Fiducial Point Delineation[1] (FPD): On-set, peak and end of main ECG waves

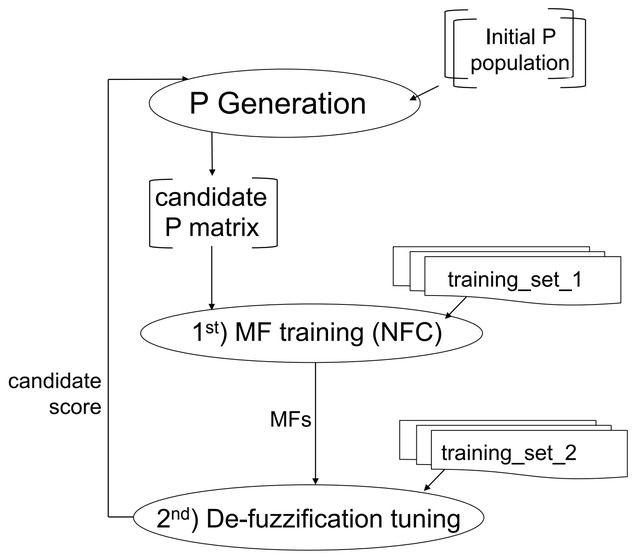


2. **Optimized Neuro-Fuzzy Classifier[4] (NFC)**
   - Adapted Feed-Forward neural structure:
     - Linearized Membership Functions (MF)
     - Rescaled overflow-free fuzzification
     - Unbalanced de-fuzzification decision



   - 16-bit integer implementation
   - Compressed RP-matrix representation to lower memory footprint

3. **Cross-platform Two-Step Training Framework**
   - Iterative training based on a Genetic Algorithm performed on PC
   - Test of optimized NFC on the WBSN

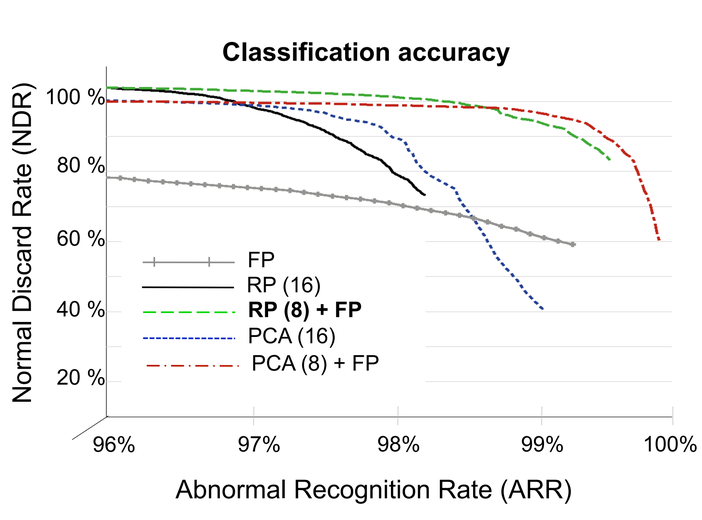


   - Optimization settings to drive GA
     - **Abnormal Recognition Rate (ARR)**: High Sensitivity to abnormalities (**min. 95%**)
     - **Normal Discard Rate (NDR)**: Maximize heartbeats discarded for detailed analysis

Experimental Results

- Evaluation Framework:
  - IcyFlex SoC (6 MHz, 96 KB of RAM)
  - 3 classes of heartbeats from MIT-BIH Arrhythmia Database[5]
- **Best Approach: RP + FPD**

MIT-BIH DB	#Heartbeats
Normal	74064
Premature Ventricular Contraction	6608
Left Bundle Branch Block	8032



Conclusions

- **Selective Advanced DSP** allows for higher **energy efficiency** in WBSNs used for cardiac monitoring
- On-node classification can be accurately performed if
  - Problem dimensionality is reduced → **RP + FPD**
  - An optimized, yet efficient scheme is used → **NFC**
- Up to **21% energy savings** can be obtained thanks to
  - **Duty cycle** reduction (up to **60%**)
  - **4x reduction in transmission bandwidth**

REFERENCES:

[1] F. Rincon et al., "Development and evaluation of multilead wavelet-based ECG delineation algorithms for embedded wireless sensor nodes," Information Tech. in Biomedicine, 2011.
[2] E. Candes et al., "Near-Optimal Signal Recovery From Random Projections: Universal Encoding Strategies?" IEEE Trans. Inf. Theory, 2006.
[3] I.T. Jolliffe, "Principal Component Analysis", Springer Verlag: New York, 2002.
[4] R. Braojos et al., "A methodology for embedded classification of heartbeats using random projections", DATE Conference, 2013.
[5] PhysioBank; http://www.physionet.org/physiobank/ (accessed on 30 April 2015).