Early Classification of Pathological Heartbeats on Wireless Body Sensor Nodes
Rubén Braojos, Ivan Beretta, Giovanni Ansaloni, David Atienza
Embedded Systems Laboratory, EPFL

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!)

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

PROPOSAL: Selective Advanced DSP
• Detailed analysis is only triggered in the presence of abnormalities

OUR STRATEGY: Heartbeat Neuro-Fuzzy Classifier for WBSNs
1. Dimensionality Reduction
   - Random Projection[2] (RP) of heartbeat provides a reduced set of coefficients

   • Adapted Feed-Forward neural structure:
     - Linearized Membership Functions (MF)
     - Rescaled overflow-free fuzzification
     - Unbalanced de-fuzzification decision

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

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:

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

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

evaluation_set_1
"Training heartbeat dataset (training_set_1)"
"Initial P matrix"
"Candidate P matrix"
"Candidate score"
"MFa"
"NFC"
"Training heartbeat dataset (training_set_2)"
"Linear approx."
"De-fuzzification tuning"
"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