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Flexible Analog-to-Feature converter for wireless smart healthcare sensors

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Introduction

Conventional wireless sensor approach for event detection

- feature extraction and classification in the aggregator
- Nyquist rate sampling + wireless transmission of all samples
⇒ **energetically inefficient**

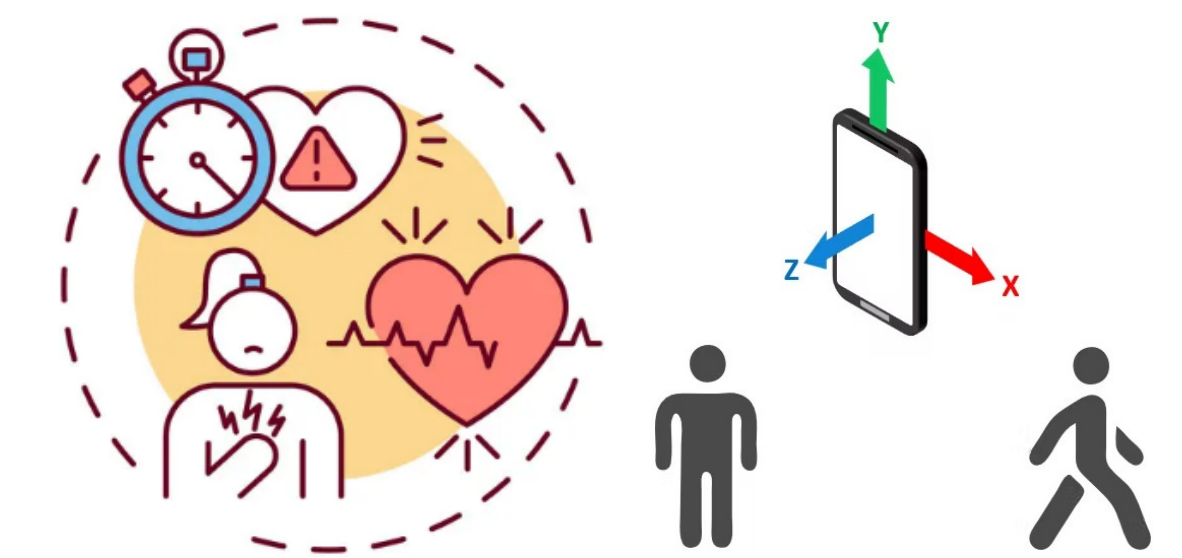
Analog-to-Feature (A2F) conversion

- extraction of only useful features from the analog signal
- features – input data for ML algorithms for further classification
⇒ **facilitation of a low-power IoT deployment**

Objective

Design of a **generic, reconfigurable A2F converter** for different low-frequency signals:

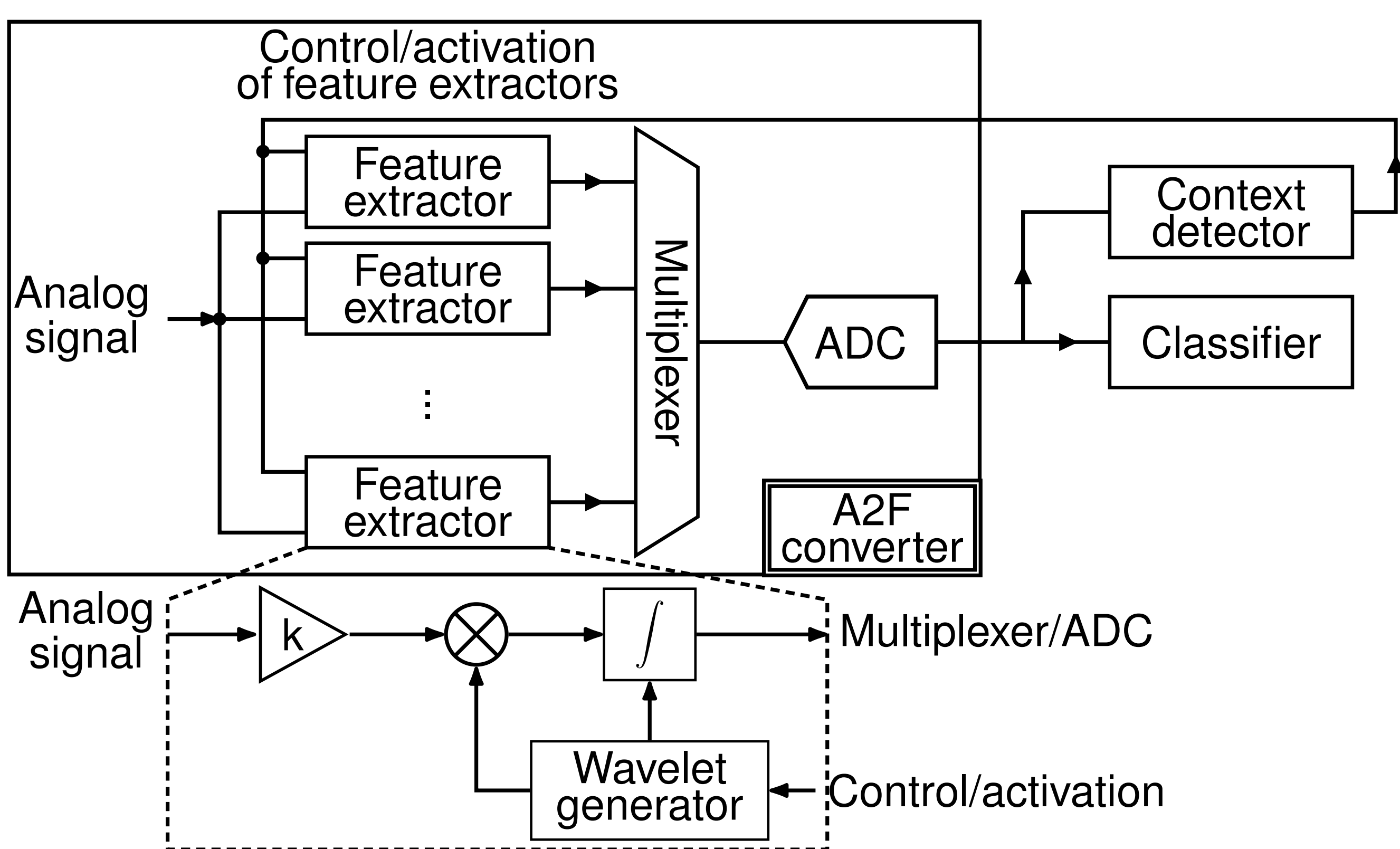
- arrhythmia detection in electrocardiogram (ECG) signals
- Human Activity Recognition (HAR) using inertial signals



Intelligent acquisition with A2F converter

Proposed architecture

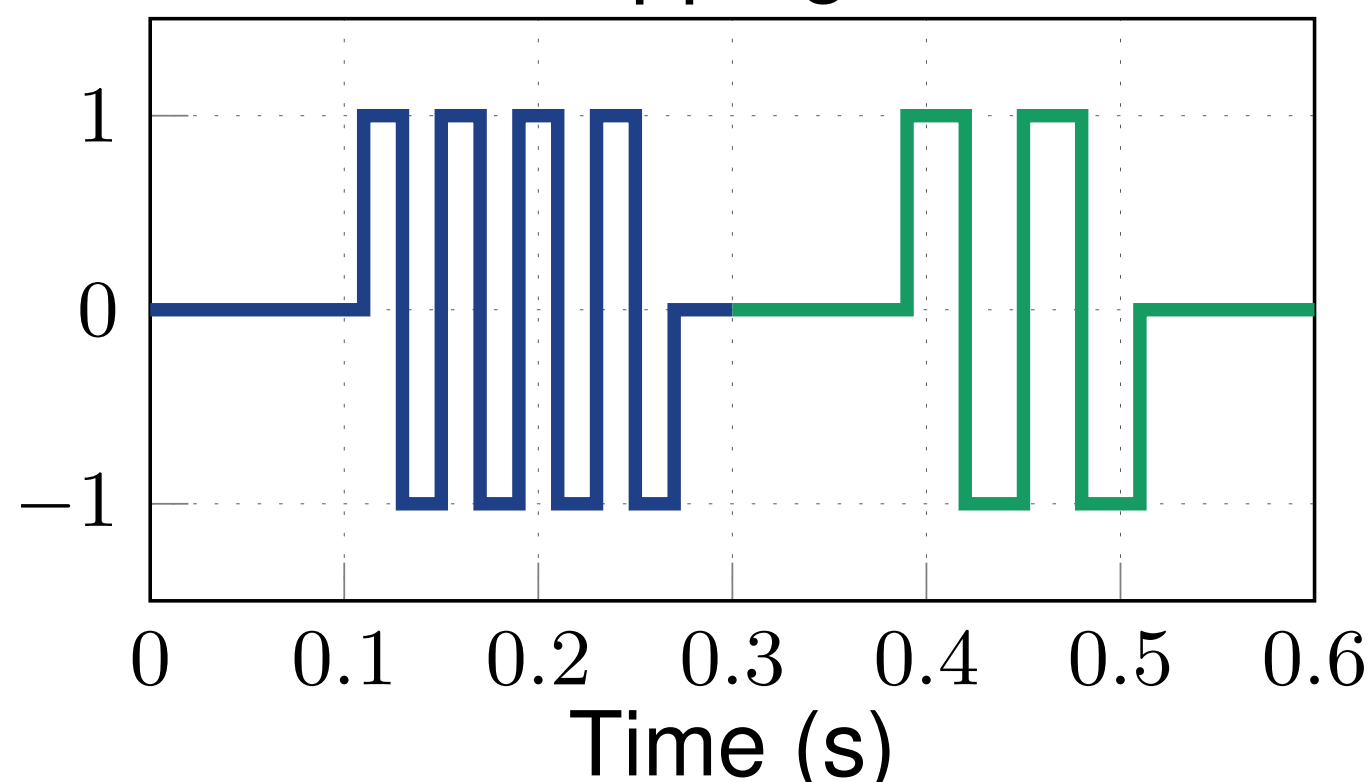
- NUWS-based feature extraction
- analog-to-digital conversion
- application-specific classification
- context detection for reconfiguration of extractors



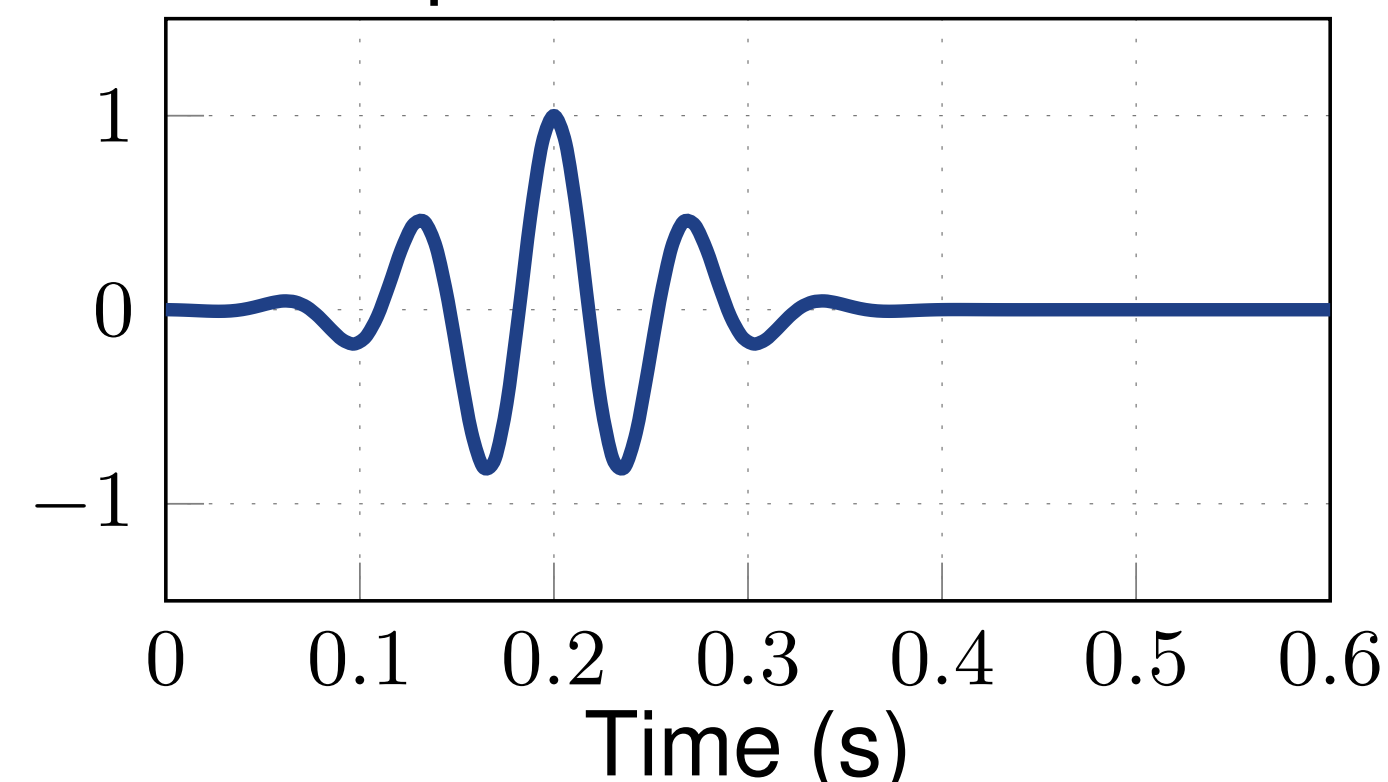
Non-Uniform Wavelet Sampling (NUWS)

- mixing with tunable wavelets + integration in the analysis window
- obtains temporal and frequency information of input signal

Two non-overlapping Haar wavelets



Real part of Gabor wavelet



large number of possible wavelets

despite reduced redundancy during the wavelet dictionaries' construction

Two-stage feature selection procedure

- Information Gain (IG)
 - independent ranking of available features
 - fast pre-selection of 100 best features without building a ML model
- Sequential Forward Search (SFS)
 - classifiers built with different subsets of features
 - improved performance for a given type of classifier

Human activity recognition

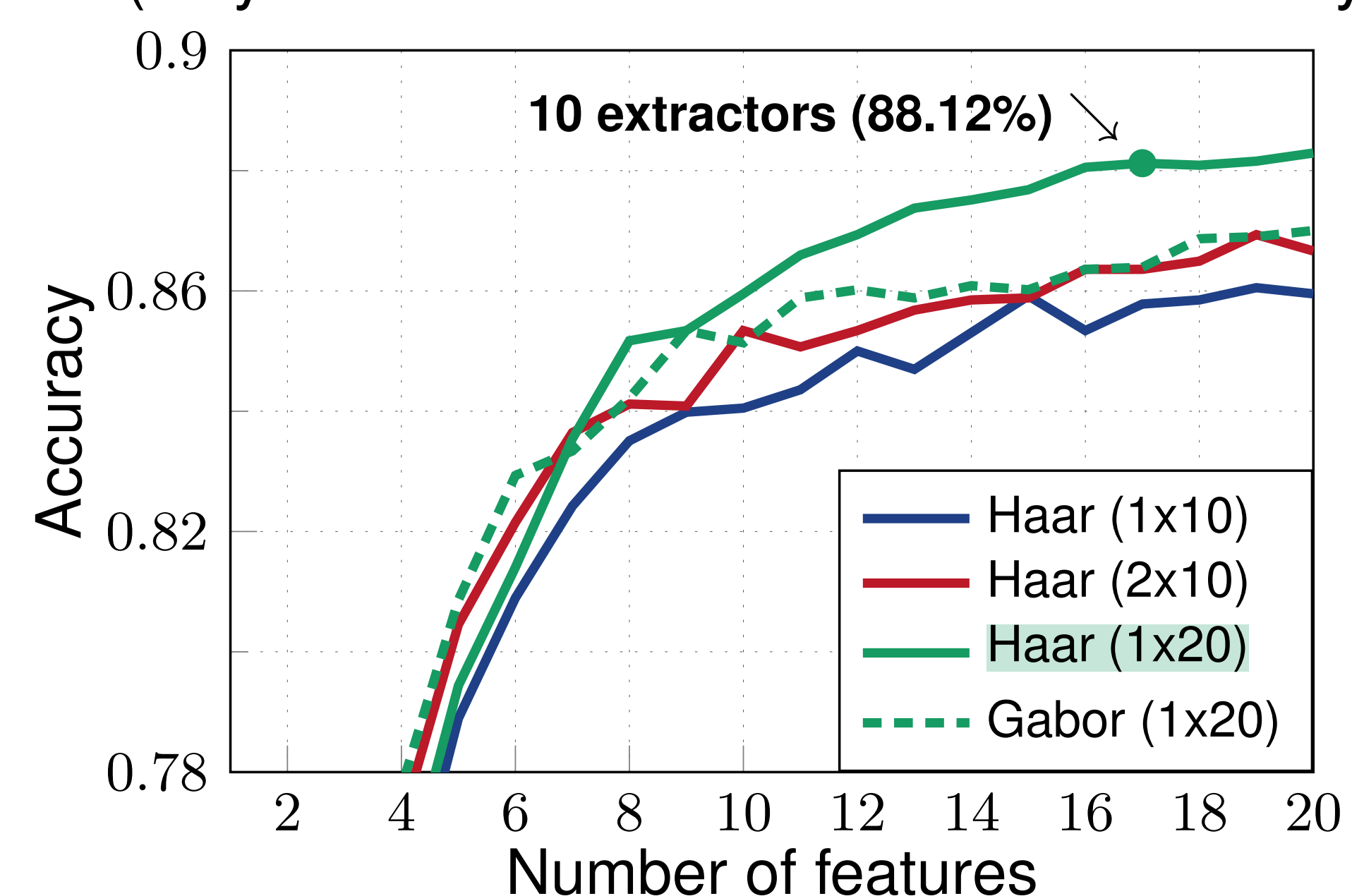
UCI-HAR dataset

- **signals:** 3-axial linear acceleration and angular velocity (50 Hz)
- **6 activities:** walking, upstairs, downstairs, sitting, standing, laying
- **training and test sets:** 70/30% random partition
- **analysis window:** 128 samples of one annotated segment (2.56 s)

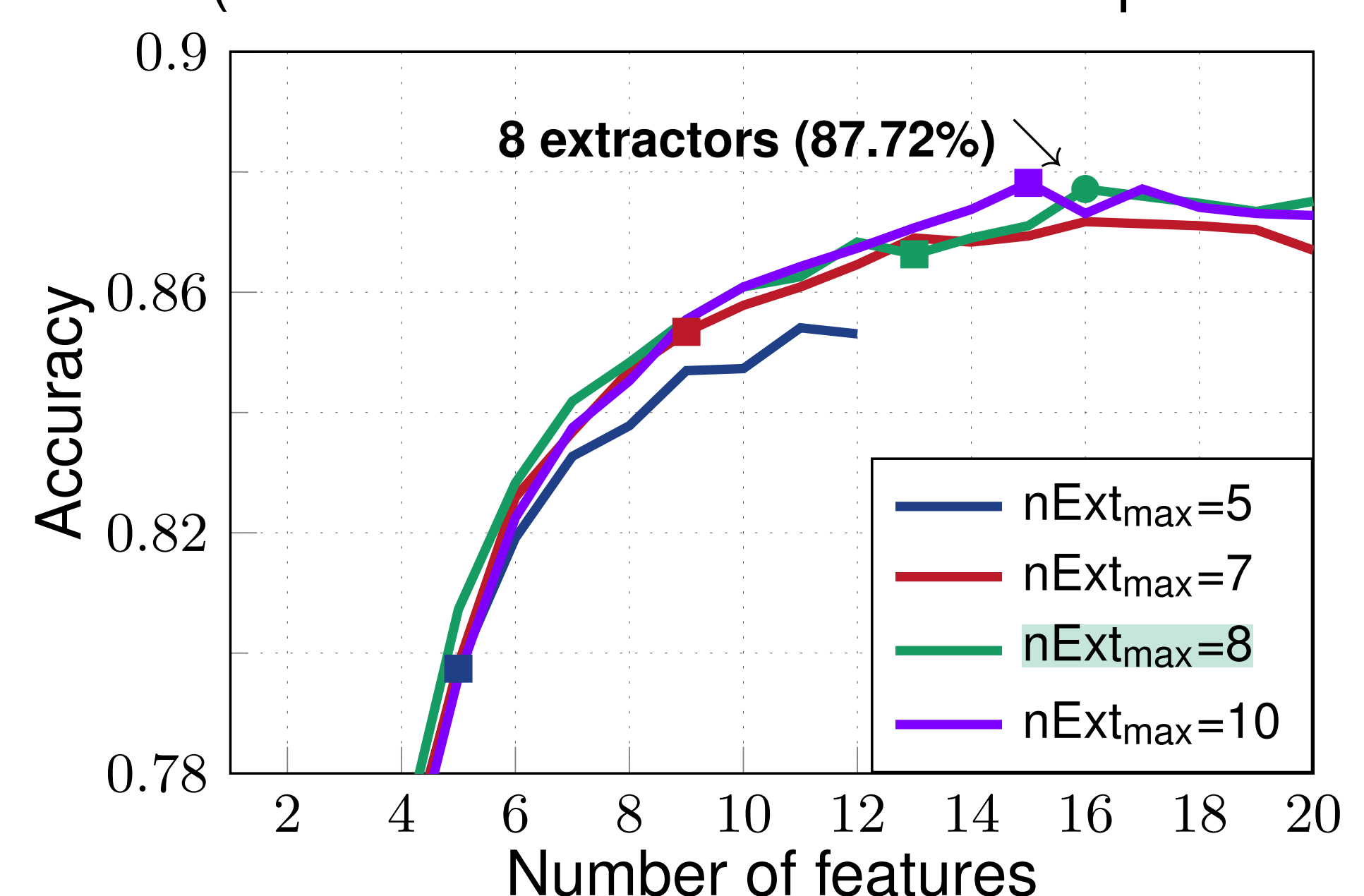
Simulation results

Multiclass classification

- **basic SFS** (only maximizes the classification accuracy)



- **adapted SFS** (limits the maximum number of parallel extractors)



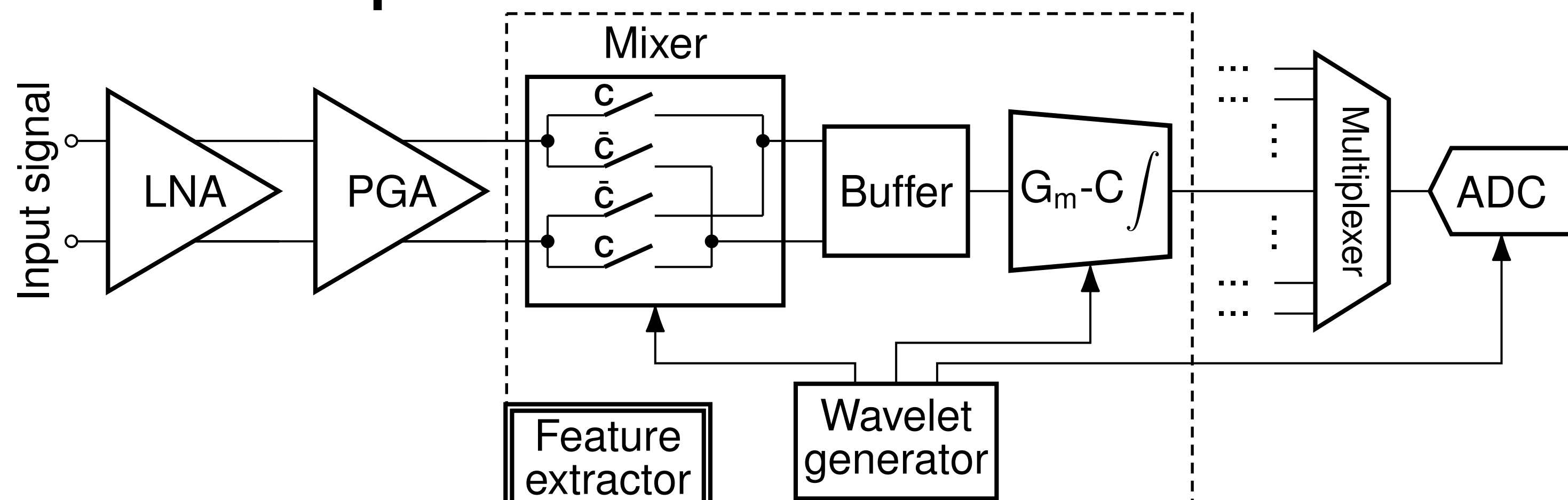
Summary

Classification	Binary (one-vs-all)	Multiclass
N° of classifiers	6	1
N° of features	58 (total)	16
N° of extractors	min=1, max=8	8
Metric value	MCC [*] _{avg} =0.860	accuracy=0.877
Extracted features	NUWS with Haar wavelets	
Classifier model	Feedforward NN (1x20) trained during 1500 epochs	

*Matthews correlation coefficient

Conclusion

Hardware implementation



Results summary

- proposal of a flexible A2F converter with NUWS-based feature extraction for event detection in wireless sensors
- simulation of HAR in addition to binary arrhythmia detection
- definition of hardware specifications for the physical implementation

Ongoing/upcoming work

- complete circuit design
- development of a modified optimized SFS algorithm – power-aware feature selection based on the circuit simulations