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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**

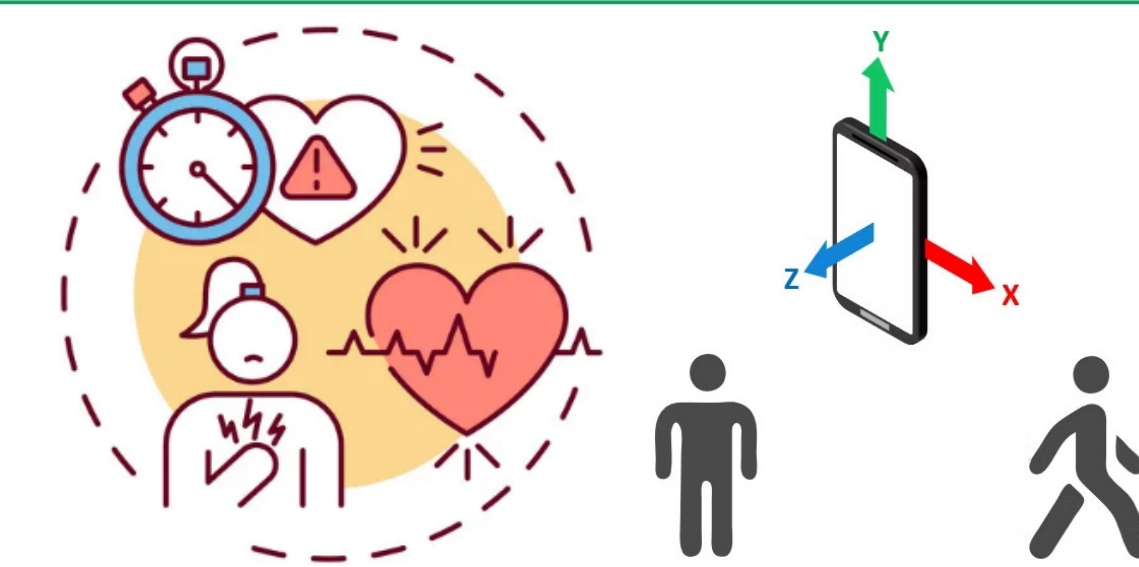
### Analog-to-Feature (A2F) conversion

- 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:

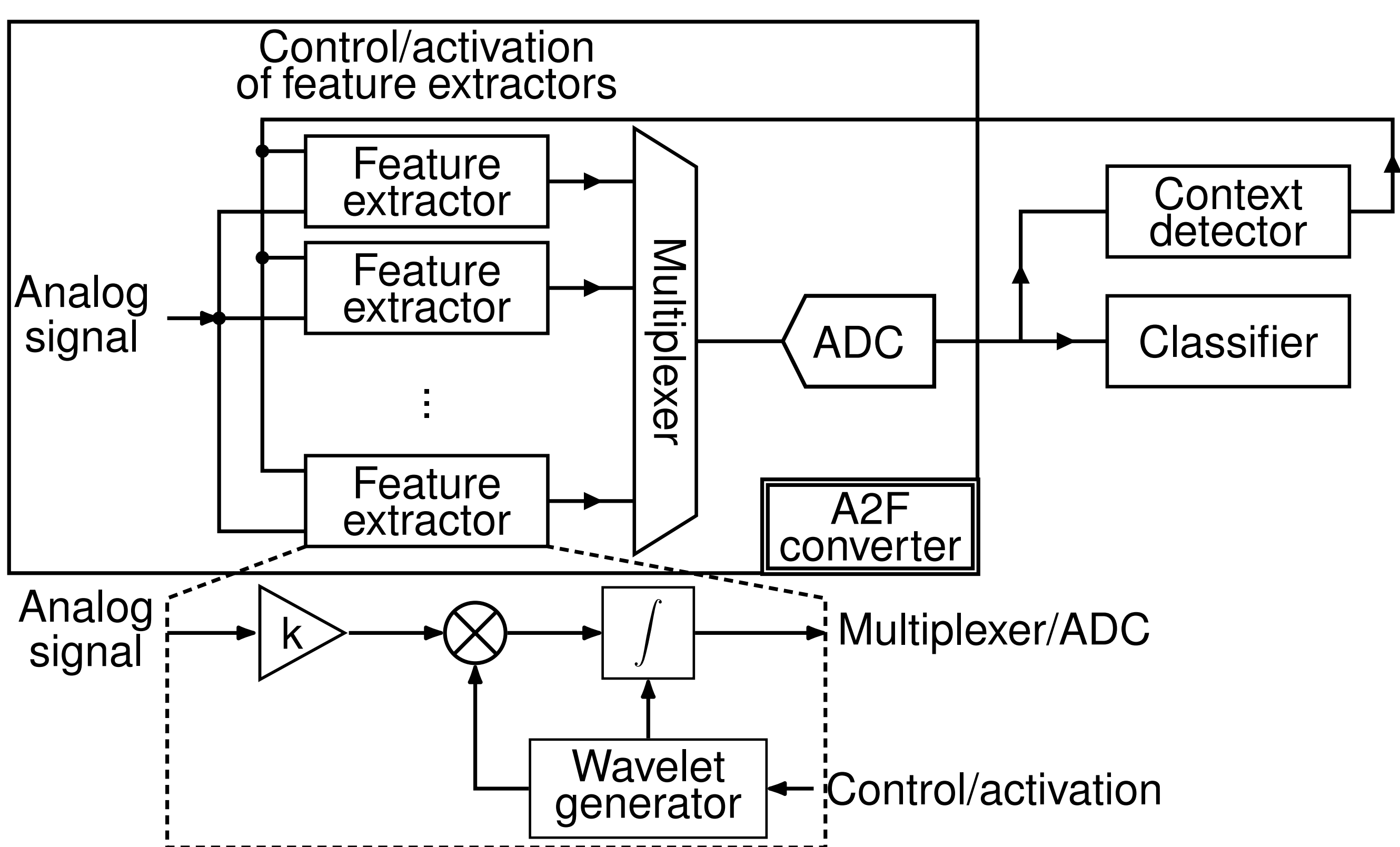
- arrhythmia detection in electrocardiogram (ECG) signals
- Human Activity Recognition (HAR) using inertial signals



## Intelligent acquisition with A2F converter

### Proposed architecture

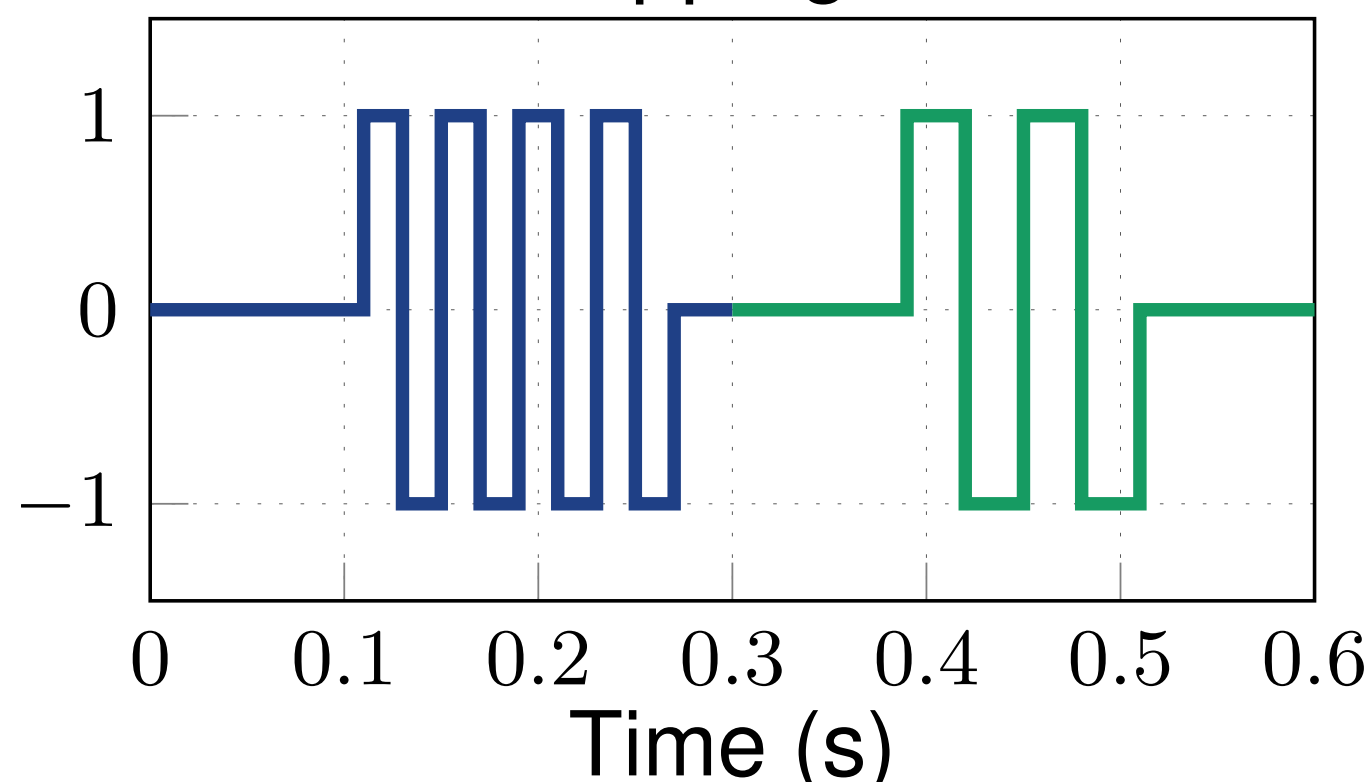
- NUWS-based feature extraction
- analog-to-digital conversion
- application-specific classification
- context detection for reconfiguration of extractors



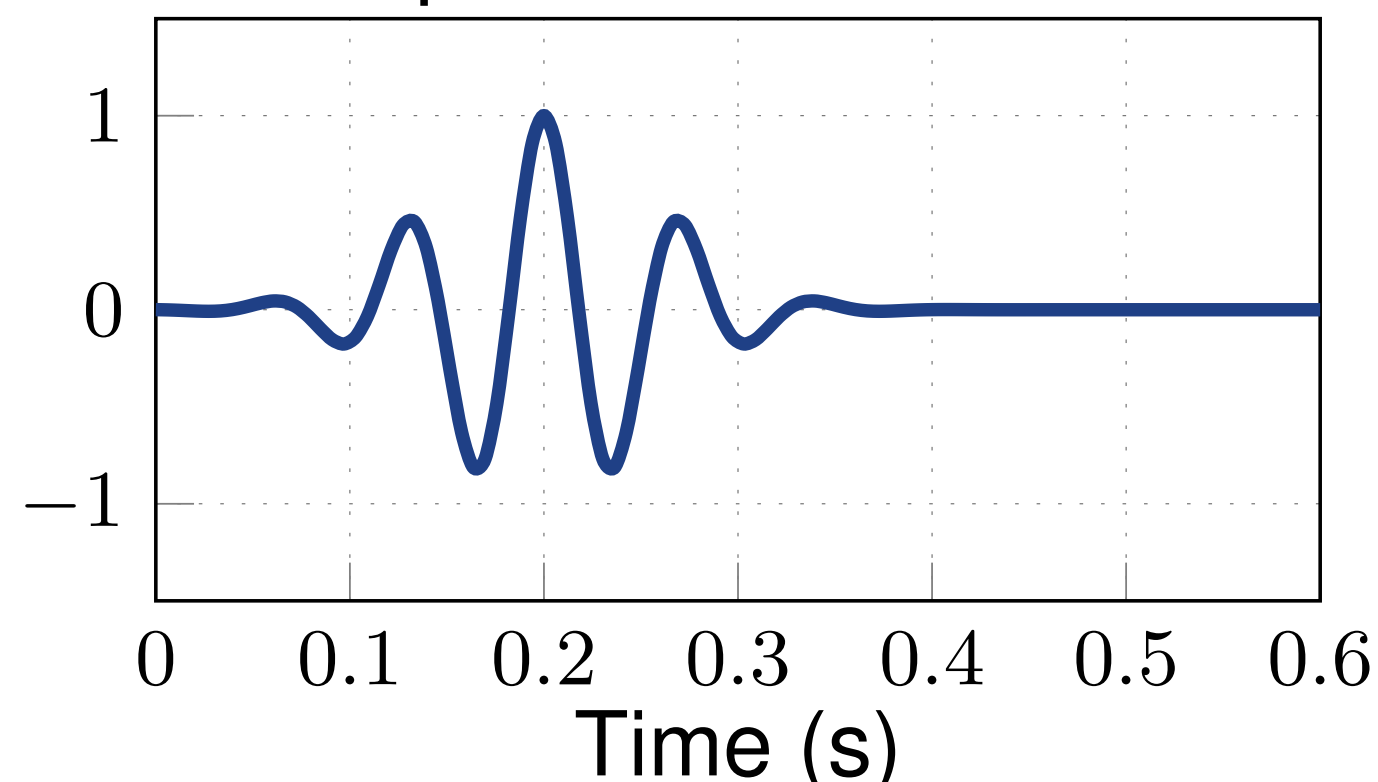
### Non-Uniform Wavelet Sampling (NUWS)

- 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

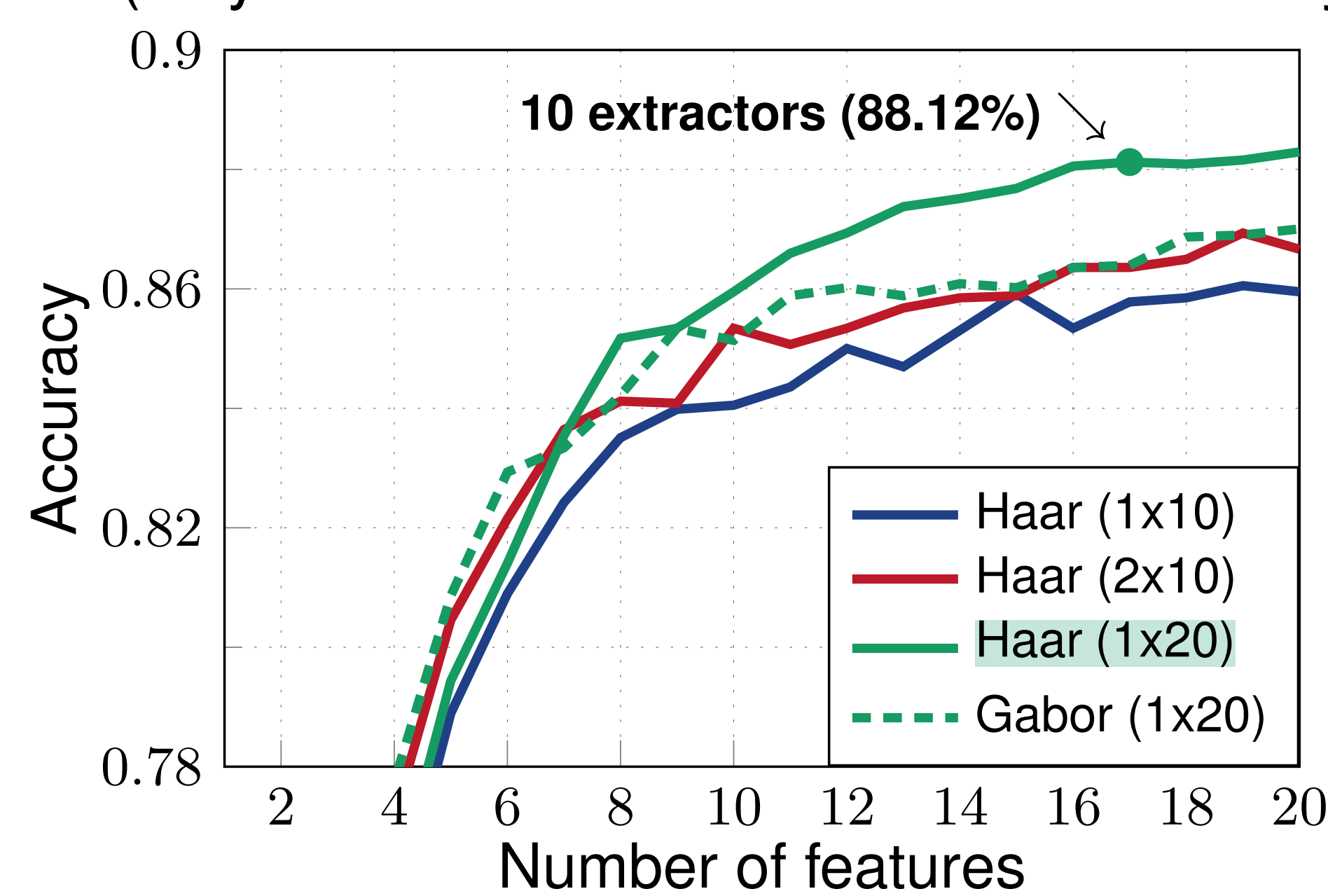
### UCI-HAR dataset

- 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)

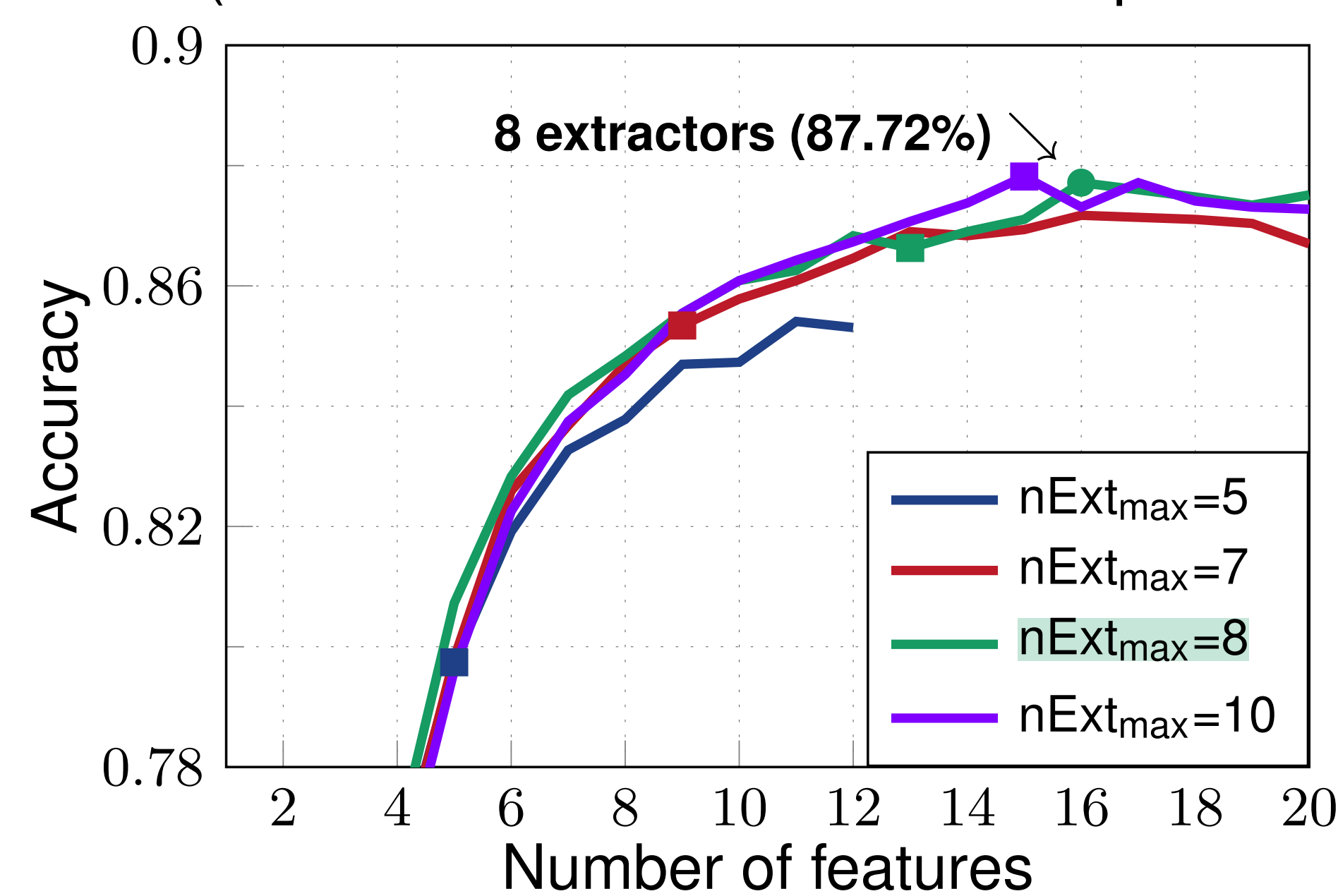
### Simulation results

#### Multiclass classification

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



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



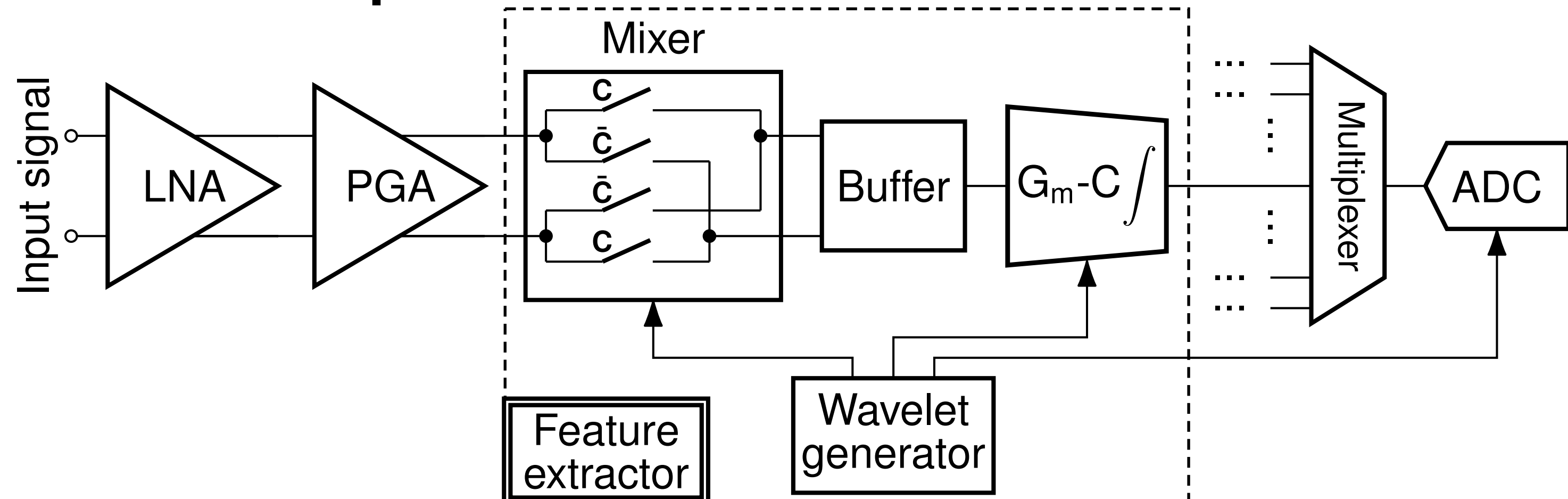
### Summary

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 <sub>avg</sub> =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