1st Invitational Workshop on
Body Area Network Technology and Applications
Future Directions, Technologies, Standards and Applications

June 19-20, 2011
Worcester Polytechnic Institute

From Embedded DSP to Embedded AI: making chronic patient monitoring intelligent and scalable

Body Area Network Technology and Applications
WPI

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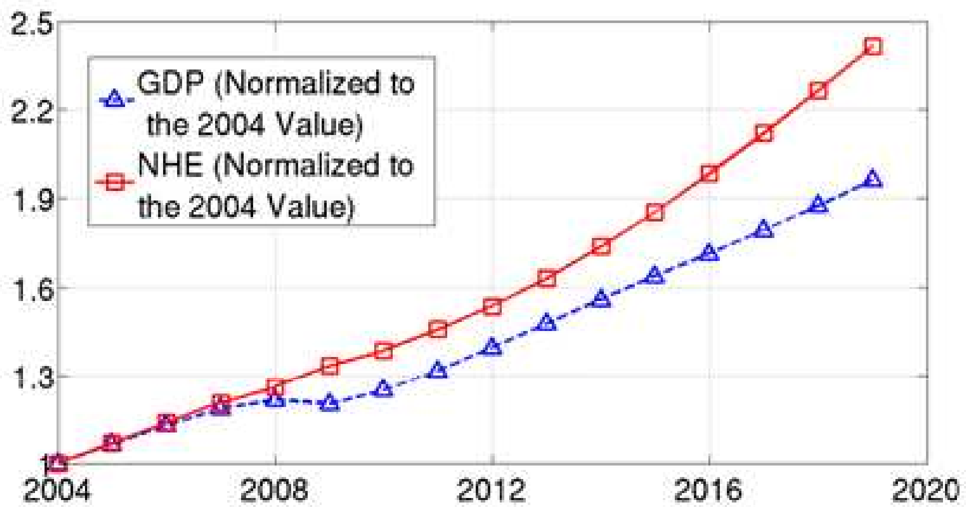
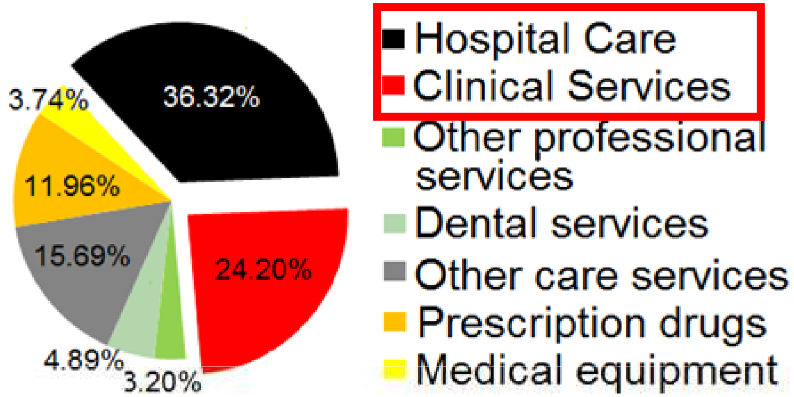
Healthcare: a problem of scale

Anticipated US GDP and NHE



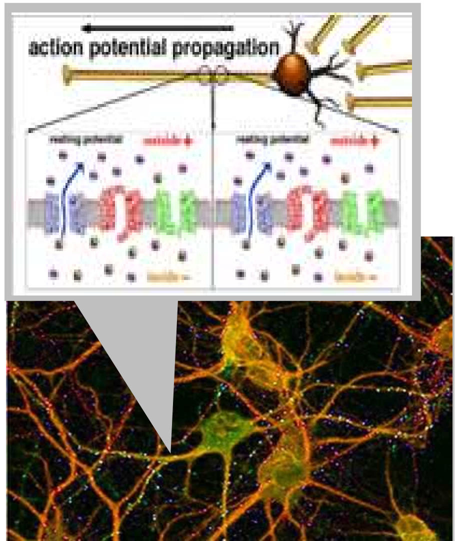
NHE breakdown

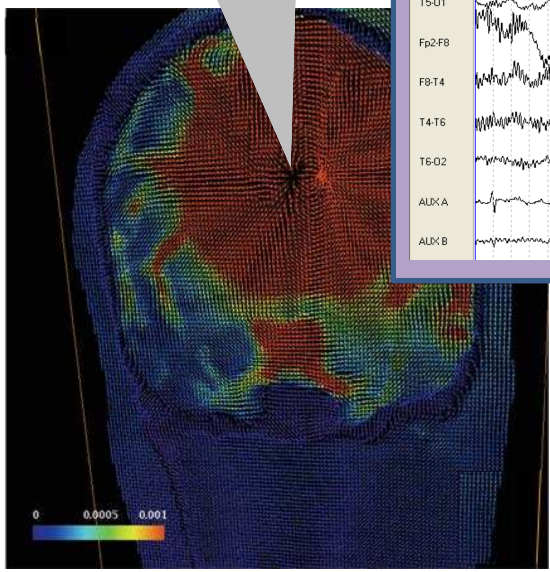


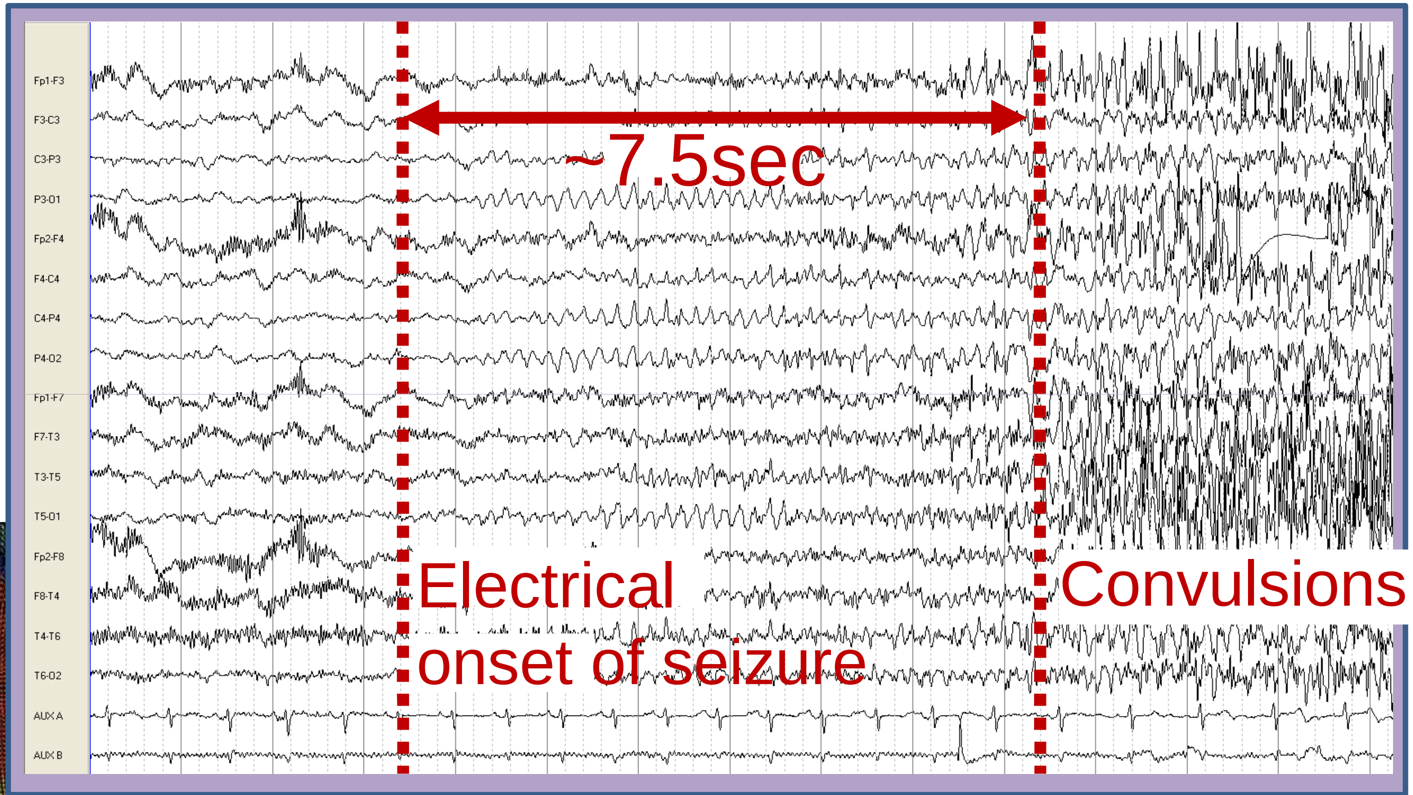
- **60% is due to hospital/clinical visits**
- **75% ($1.3T) is due to management of chronic disease and conditions (chronic disease causes <u>70% of deaths</u>)**

Aim is to translate scalability of technology
into scalability of clinical responsiveness

Clinical inference: what does this signal mean?

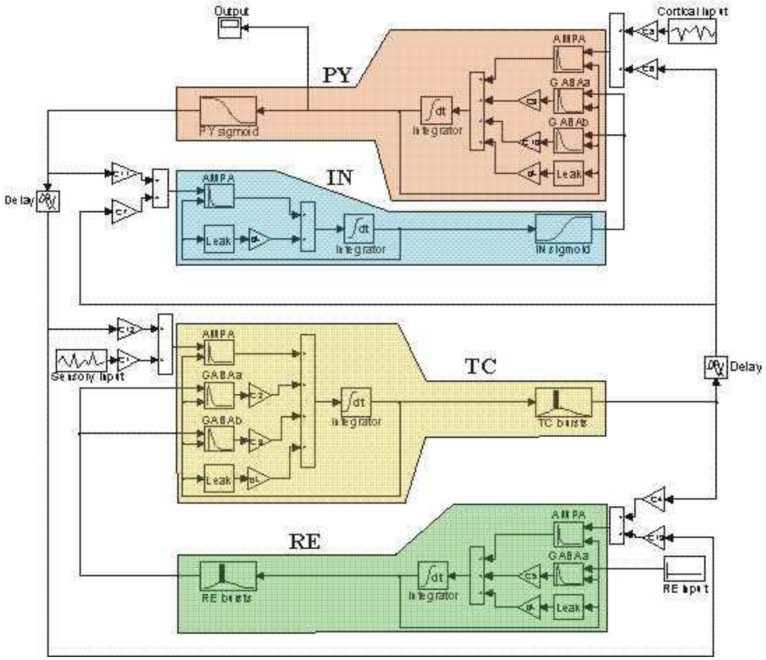






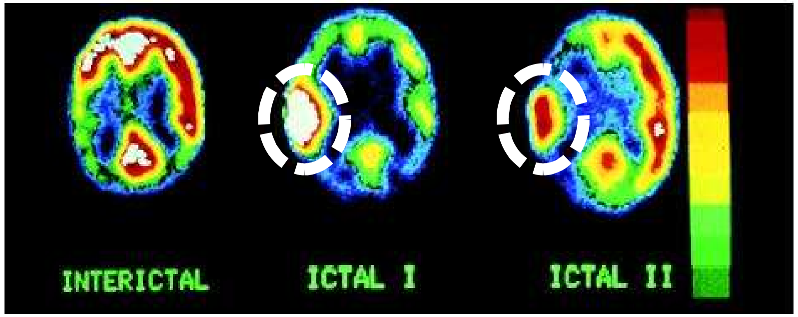
Why is it hard? (I)

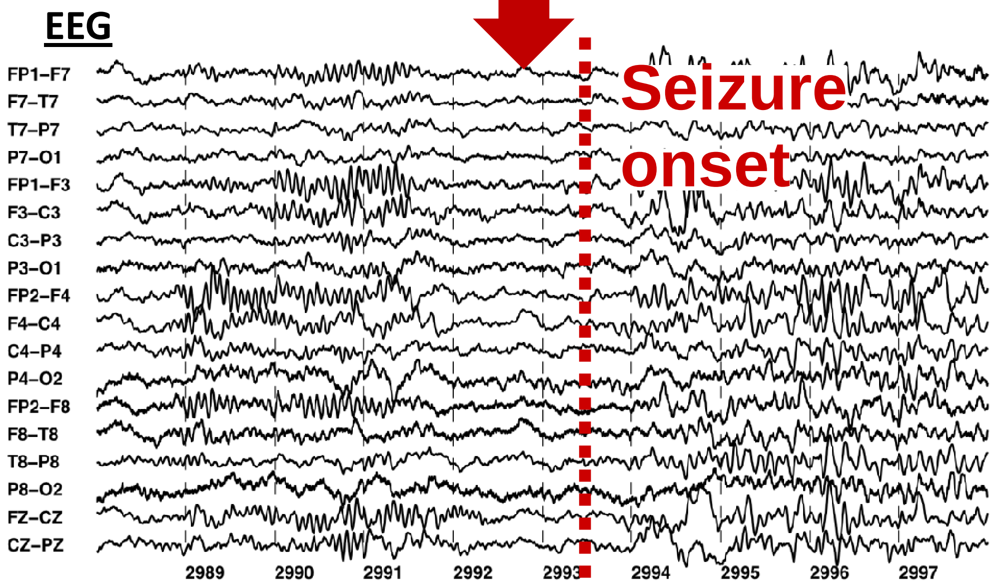
Signals from low-power chronic sensors are non-specific



[Suffczynski, *Neuroscience'04*]

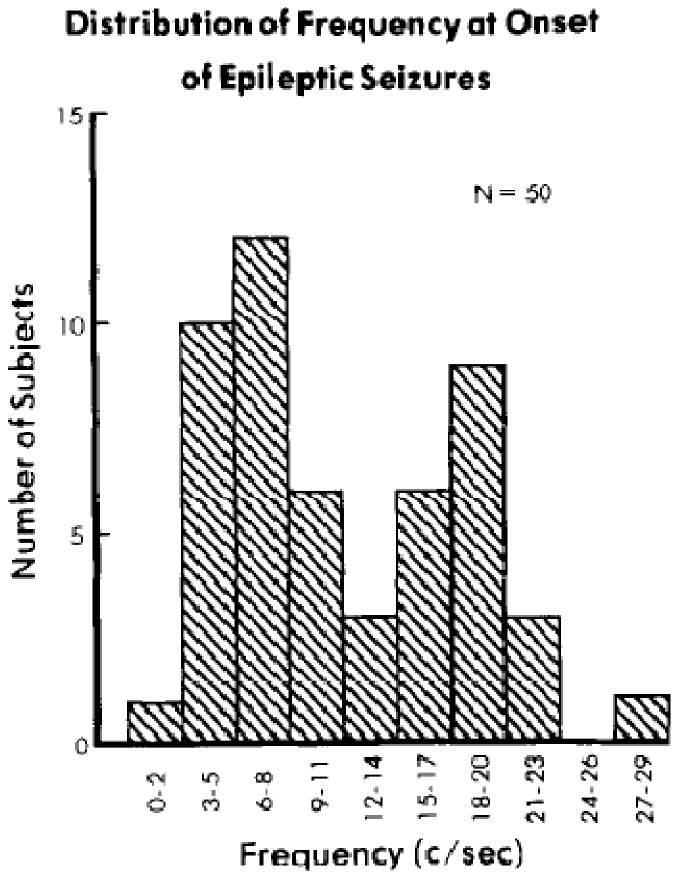
Single-photon emission computed tomography (SPECT)





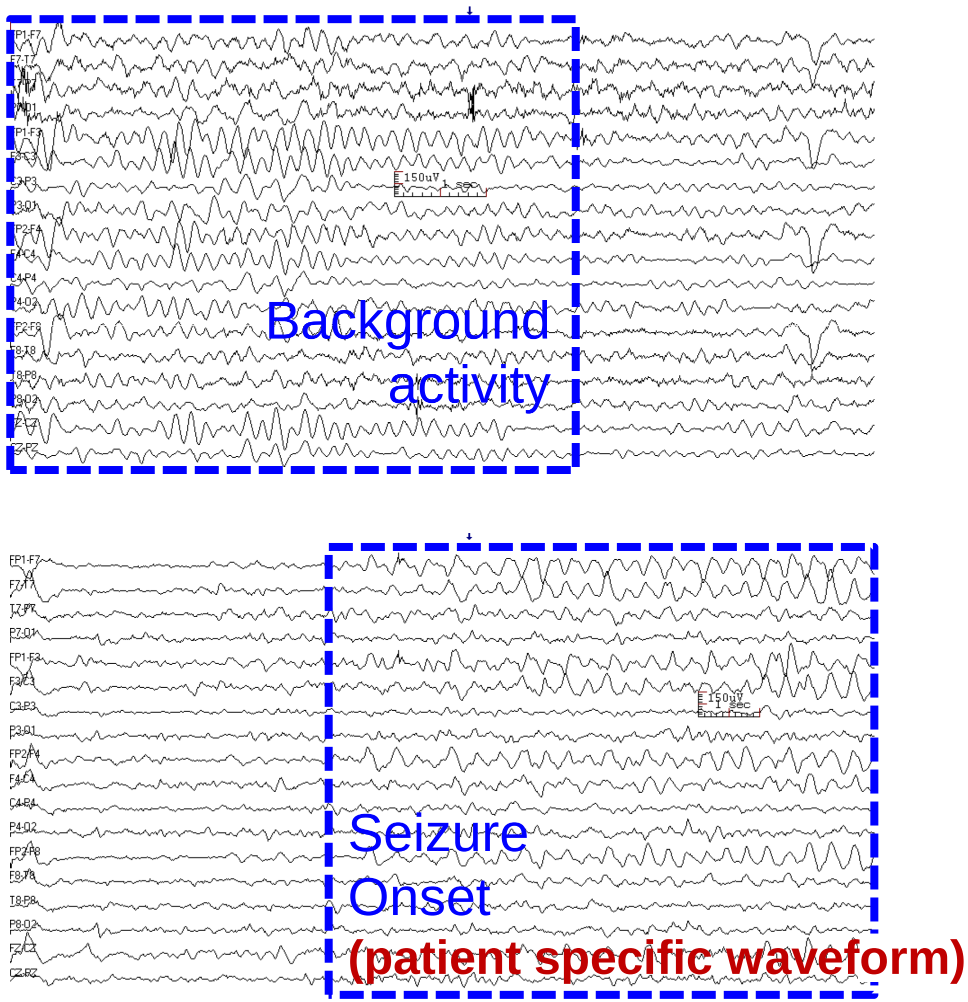
Why is it hard? (II)

Expression of disease states is variable over patients & time



[Gotman, *EEG & Clinical Neurophis.'81*]

Patient A EEG:



Constructing and applying high-order models

Enabling data-driven patient-monitoring networks through…

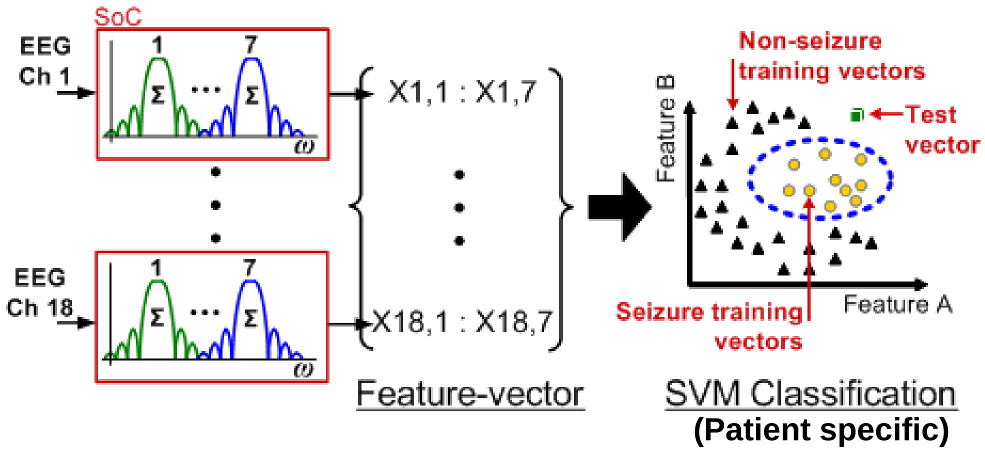
1) Efficient techniques for data analysis

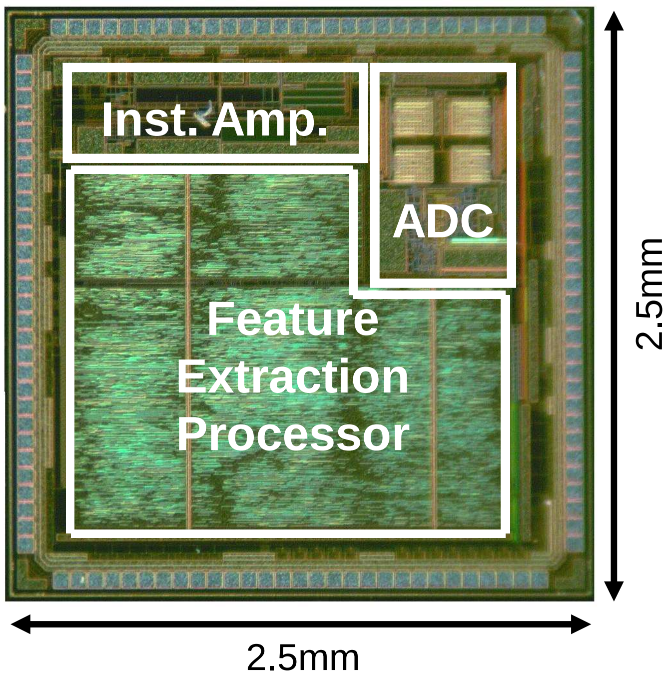
- Utilize methods from the domain of supervised machine-learning
- Embed these in low-power platforms and devices

2) Availability of physiological data

- Exploit patient databases from the healthcare domain
- Exploit data acquisition capability of the sensor network

Towards devices: seizure detection IC



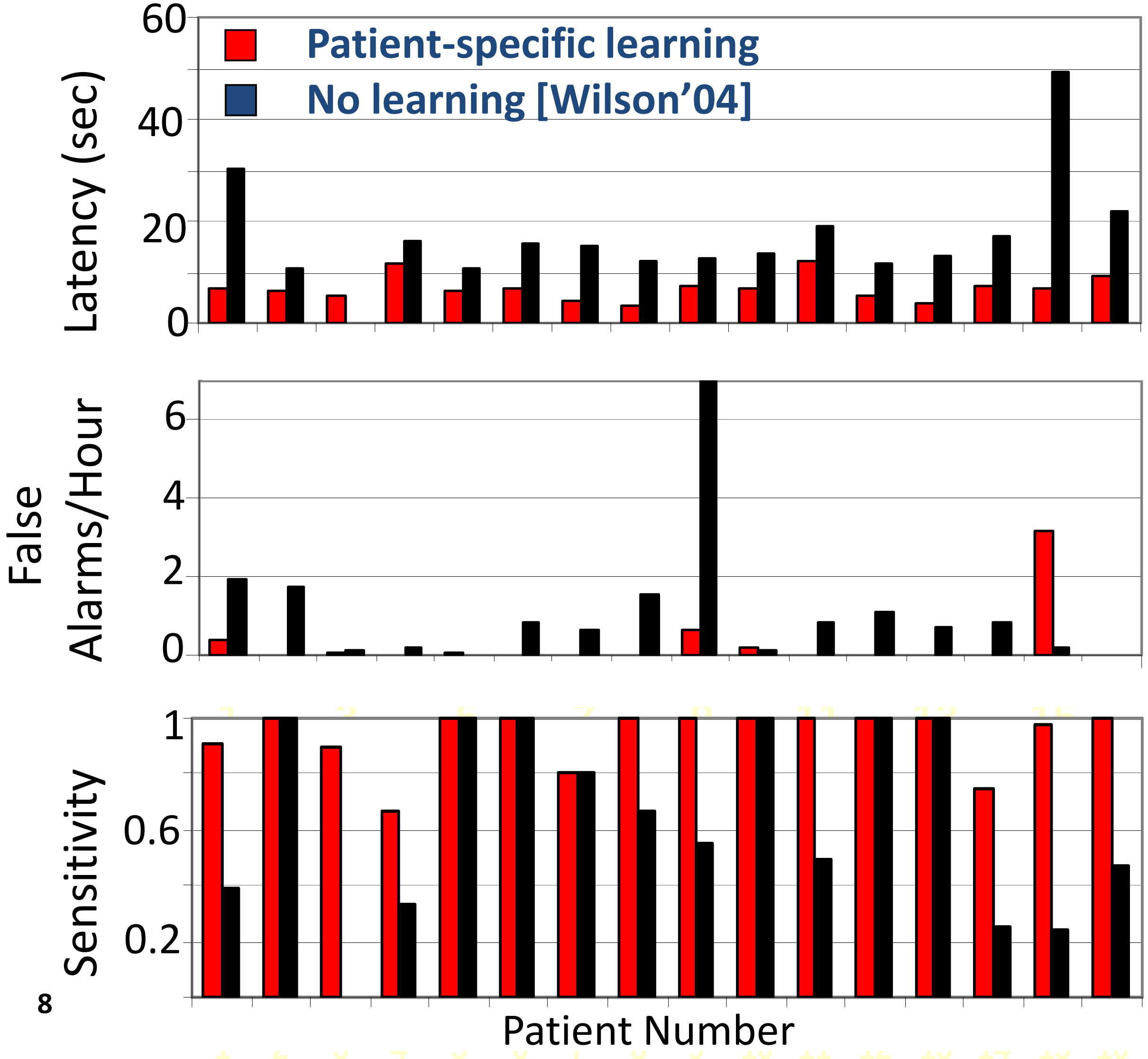


Supply voltage	1V
I-amp LNA power	3.5μW
I-amp input impedance	>700MΩ
I-amp noise (input referred, 0.5Hz-100Hz)	1.3μVrms
I-amp electrode offset tolerance	>1V
I-amp CMRR	>60dB
ADC resolution	12b
ADC energy per conversion	250pJ
ADC max. sampling rate	100kS/s
ADC INL/DNL	0.68/0.66LSB
ADC SNDR	65dB
Digital energy per feature-vector	234nJ
Feature vector computation rate	0.5Hz
Total energy/feature-vector per EEG channel	**9μJ**

[JSSC, April'10]

Impact of patient–specific modeling

536 hrs of patient tests:



Latency:

- Specific: 6.77 ± 3.0 sec
- Non-sp.: 30.1 ±1 5 sec

False alarms:

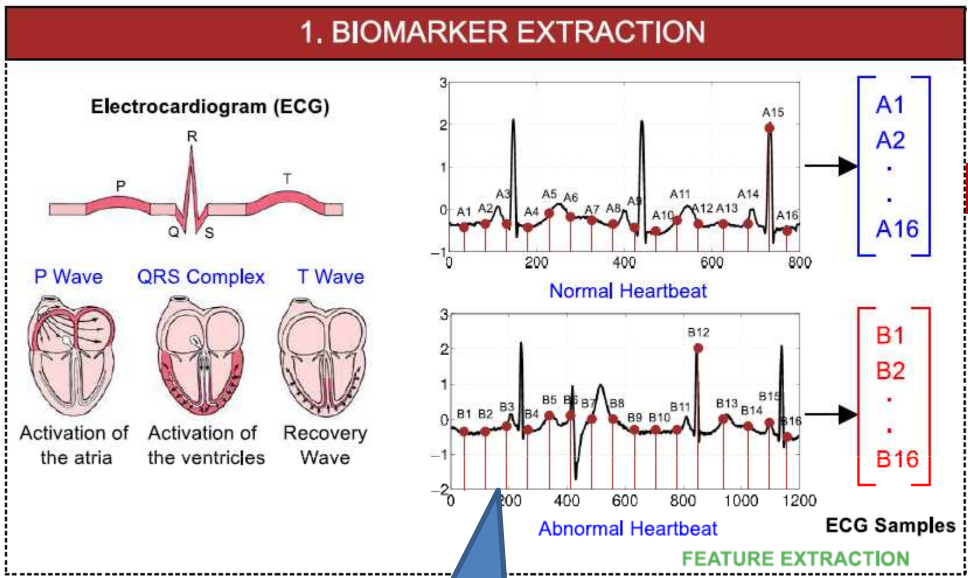
- Specific: 0.3 ± 0.7 /hr
- Non-sp.: 2.0 ± 5.3 /hr

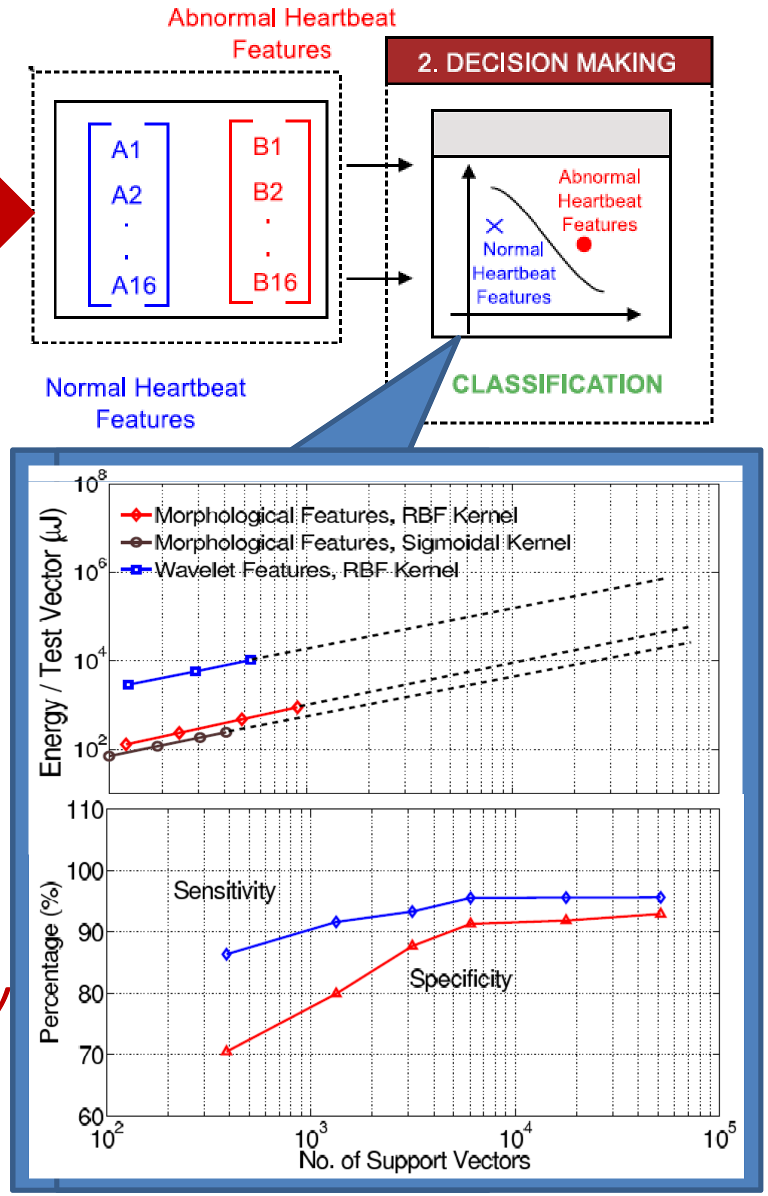
Sensitivity:

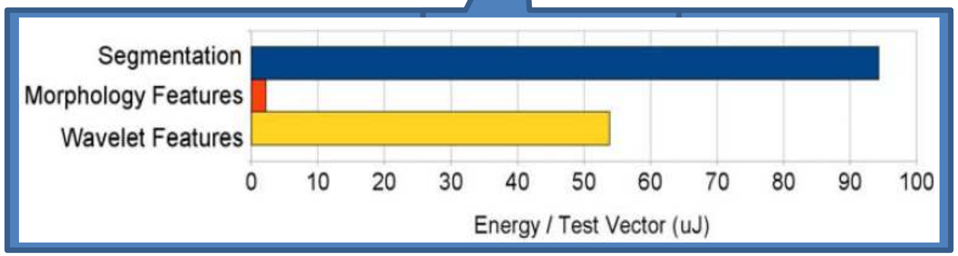
- Specific: 0.93
- Non-sp.: 0.66

[Shoeb, EMBC'07]

Computational energy: ECG beat detection







Classifier energy scales w/ model complexity

<u>real patient data → complex models</u>

[DAC'11]

Expanding the standards

Telemetry

www.continuaalliance.org

Selected patient-specific data

Patient data & models

Clinical experts (centralized & limited resources)

Summary

Physiological expressions in low-power sensing modalities
Are non-specific and variable from patient-to-patient

Data-driven methods provided systematic approaches for constructing high-order models

Need:

Algorithms
(identify data instances to present to experts)

Platforms
(exploit algorithmic structure for low energy & flexibility)

Networks
(selective utilization of clinical resources)