# Realization of electronic systems operating on dynamical physical signals

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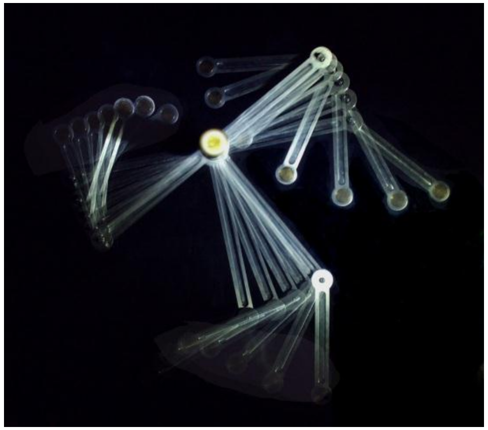
# Outline

- Dynamical electronic systems
  - Definition, comparison to physical dynamical systems
  - Example from epileptic seizure prediction
- Design methodology for dynamical electronic systems
  - Typical design flow, goals and challenges
  - System scenarios
  - Methodology overview
  - Proposed top-down scenario clustering approach
- System scenarios for Lyapunov exponent calculation
  - Energy saving results
  - Comparison to theoretically best solution

# Dynamical physical systems

- Processes which are evolving in time
- Characterized by:
  1. A state space $\boldsymbol{S}$, where a state is represented by a number of variables that describe the physical situation
  2. A set of times $\boldsymbol{T}$, continuous or discrete, at which the state of the system is evaluated
  3. A rule $\boldsymbol{R}$ that specifies how the consecutive state(s) of a state $\boldsymbol{s} \in \boldsymbol{S}$ should be found: $\boldsymbol{R}: \boldsymbol{S} \times \boldsymbol{T} \rightarrow \boldsymbol{S}$



Double pendulum

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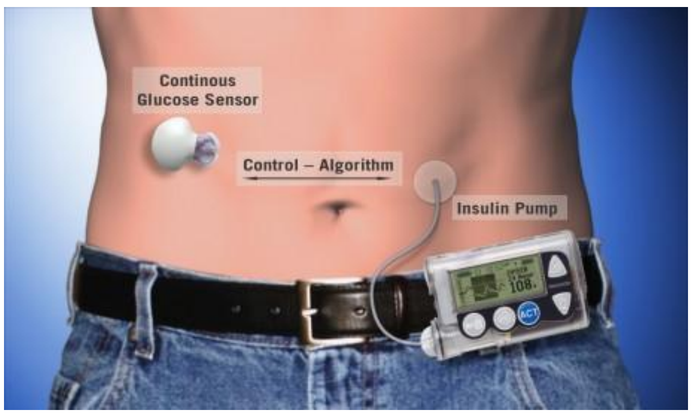
# Dynamical electronic systems

In Electronics:

"Dynamism is the system property that enables the system behavior to adapt at run-time under the influence of changing environmental stimuli."




**Mobile healthcare systems**


**Mobile audio-visual media devices**

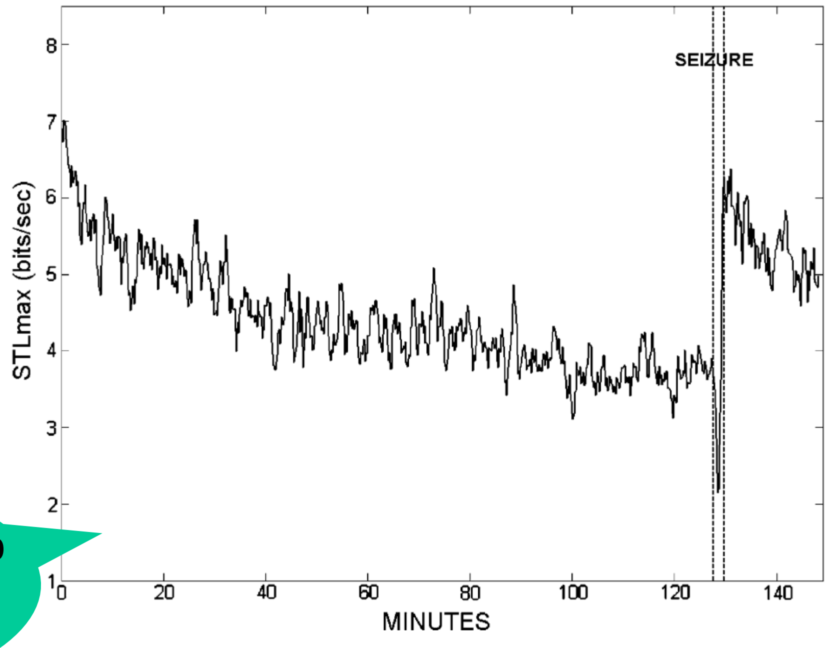

**Smartphones**

**Wireless network devices**

Ma et al., *Systematic Methodology for Real-Time Cost Effective Mapping of Dynamic Concurrent Task-Based Systems on Heterogeneous Platforms,* 2007.

# Epileptic seizure predictor

- Software algorithm developed by Prof. L. Iasemidis et al., Arizona State University, Tempe, USA
- Long-term prospective on-line real-time prediction of seizures
- Based on maximum short-term Lyapunov exponent (STLmax) estimated from EEG signals



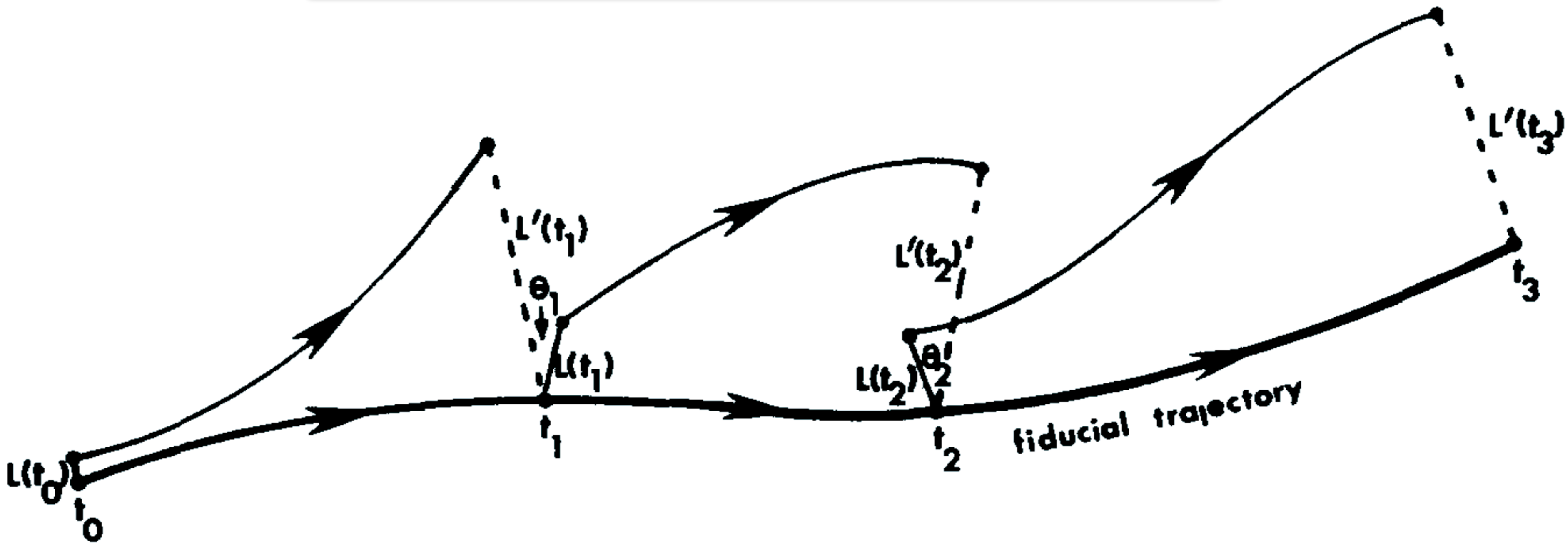


Warning! You are going to have a seizure within the next three hours!

Iasemidis et al. *Seizure prediction and its applications,* 2011

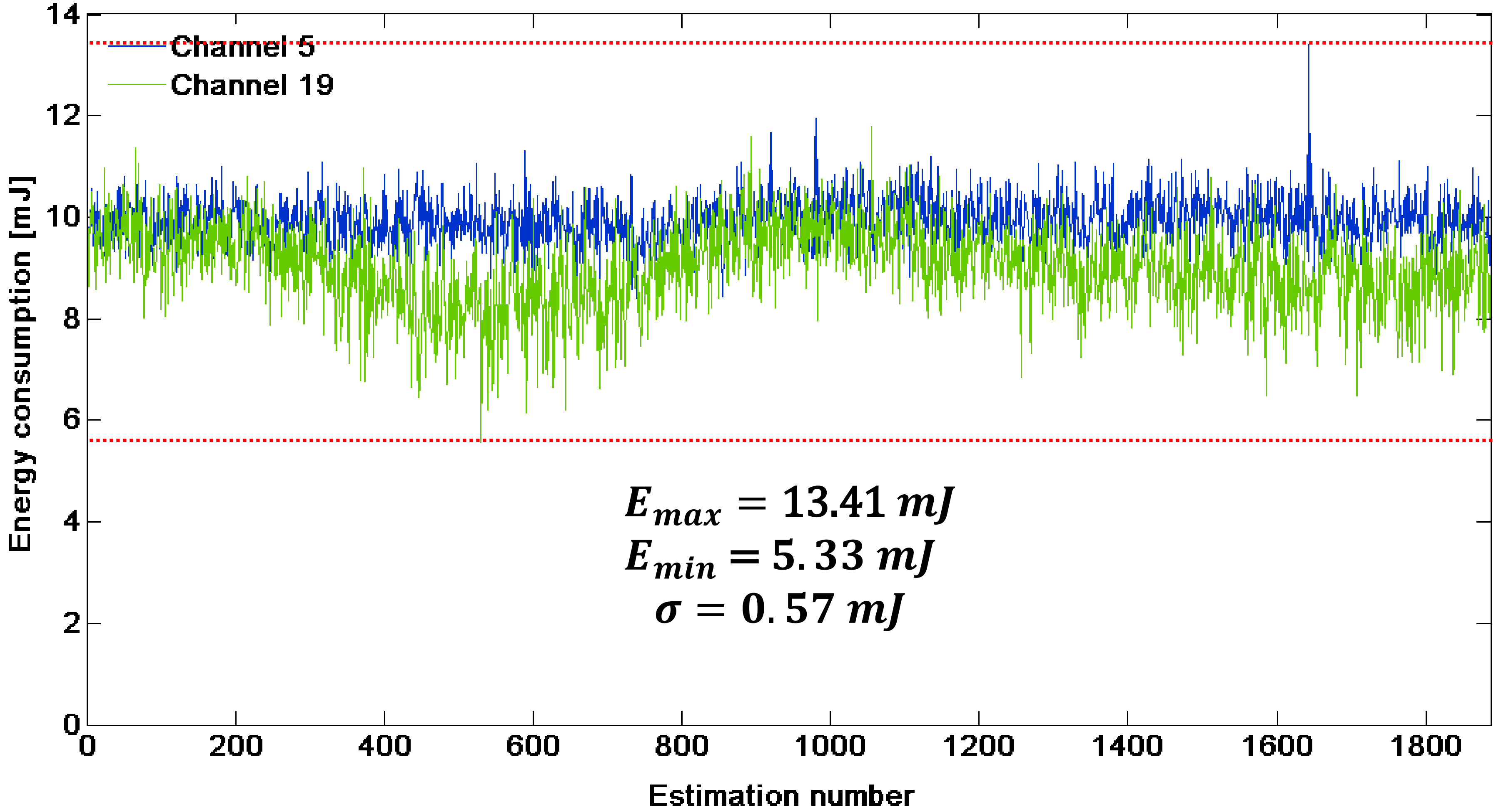
# Estimation of STLmax from experimental time series

$$STLmax = \frac{1}{t_M - t_0}\sum_{i=1}^{M} log_2 \frac{L'(t_i)}{L(t_i - 1)}$$

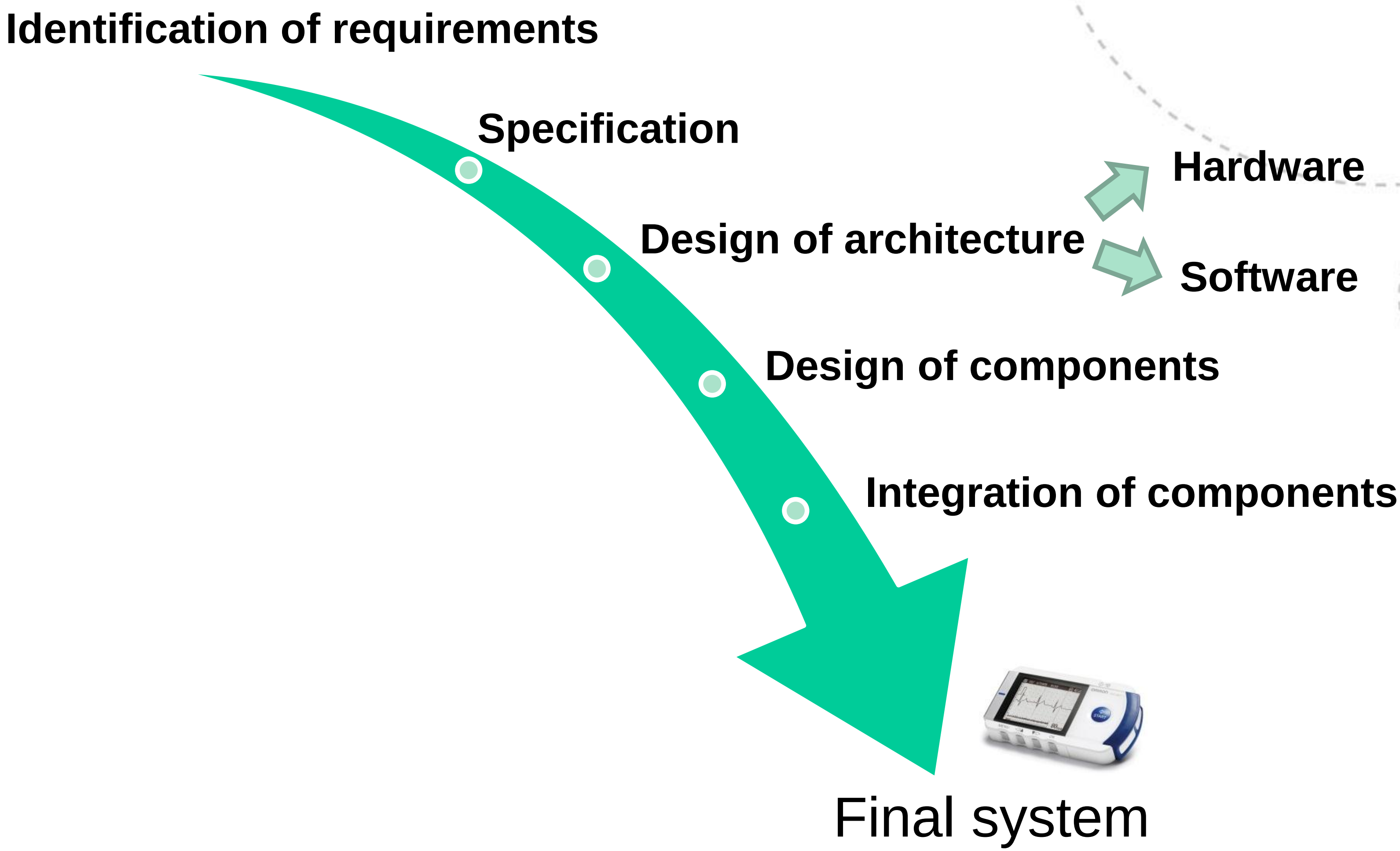


# Dynamism in STLmax estimation

- Experiments performed on CoolBio DSP processor:



# The Embedded System Design Process



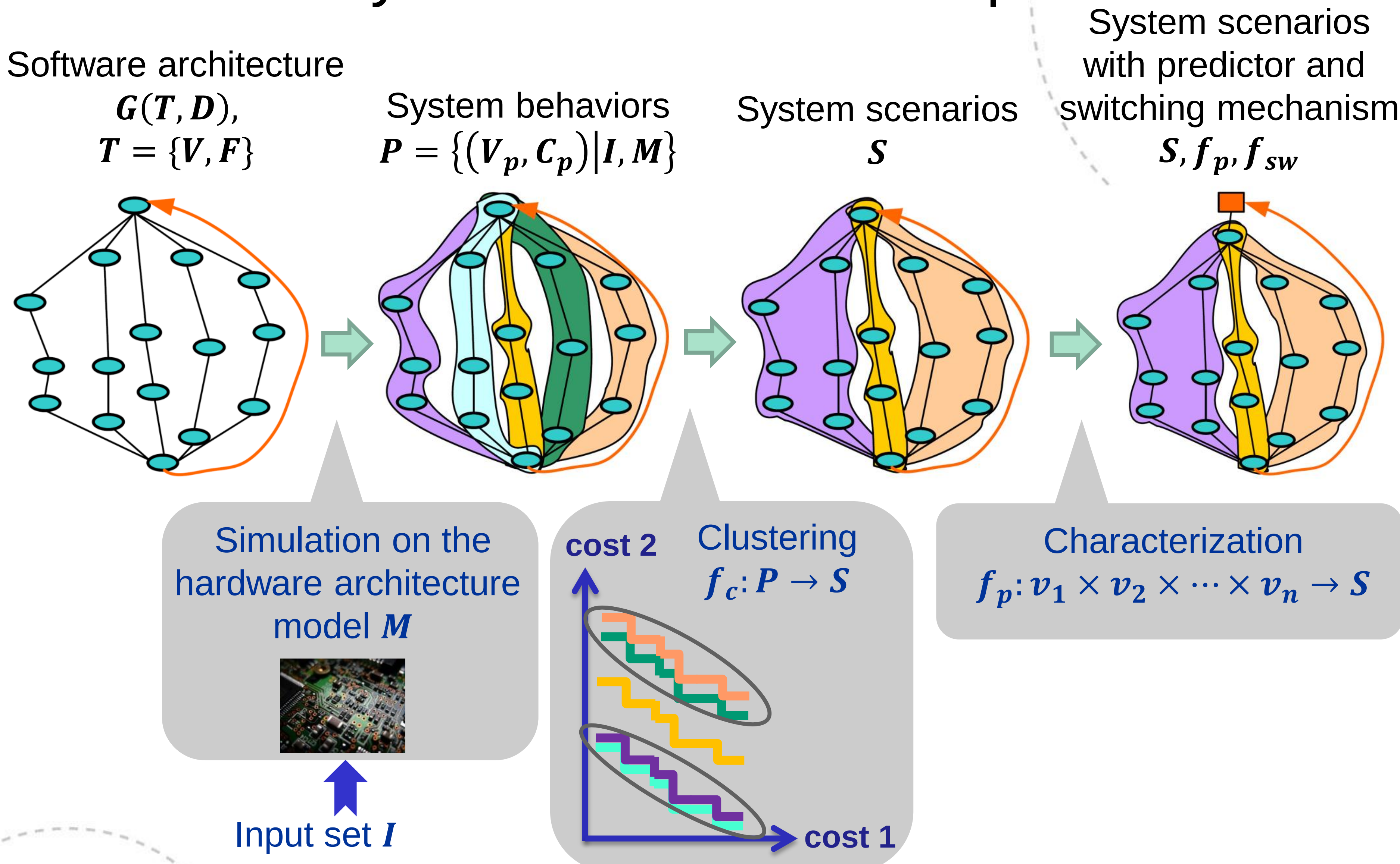

W. Wolf. *Computers as Components, Principles of Embedded Computer System Design* 2005

# System scenario concept

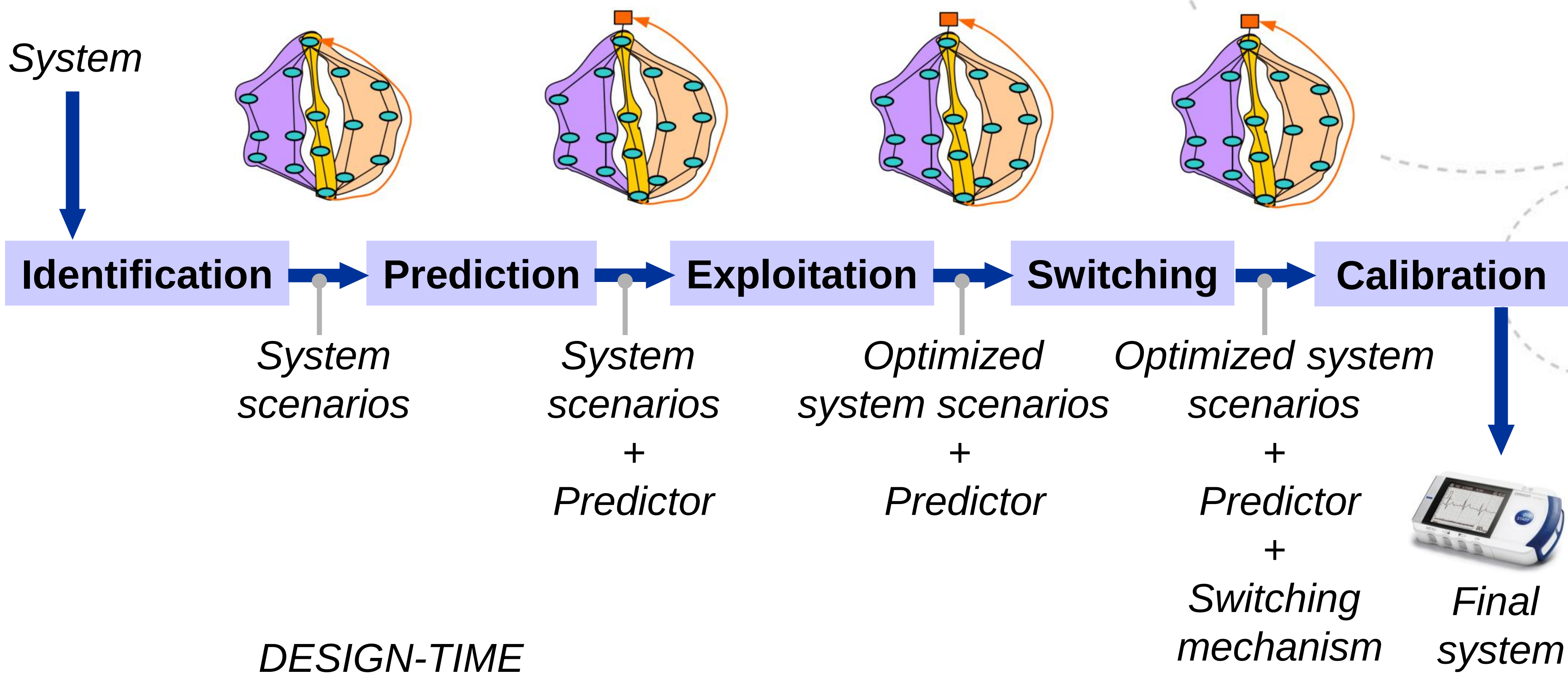
«***System scenarios*** group system behaviors
that are similar from the multidimensional cost perspective,
such as resource requirements, delay and energy consumption,
in such a way that the system can be configured
to exploit this cost similarity.»

Gheorghita et al. *System Scenario based Design of Dynamic Embedded Systems,* 2008

# System scenario concept

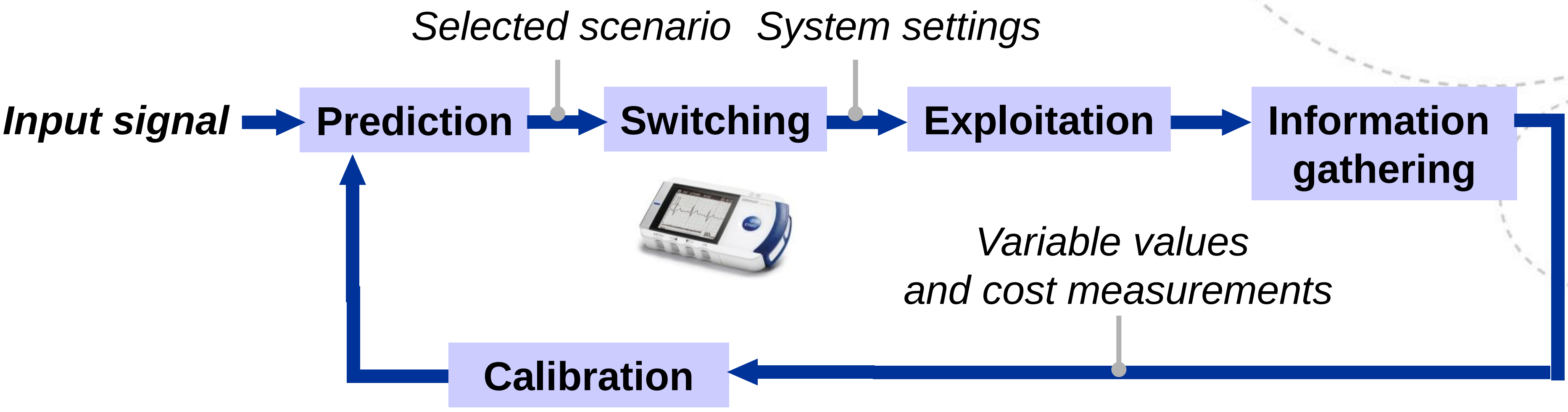


# System scenario based design methodology




Gheorghita et al. *System Scenario based Design of Dynamic Embedded Systems,* 2008

# Overview of completely designed system



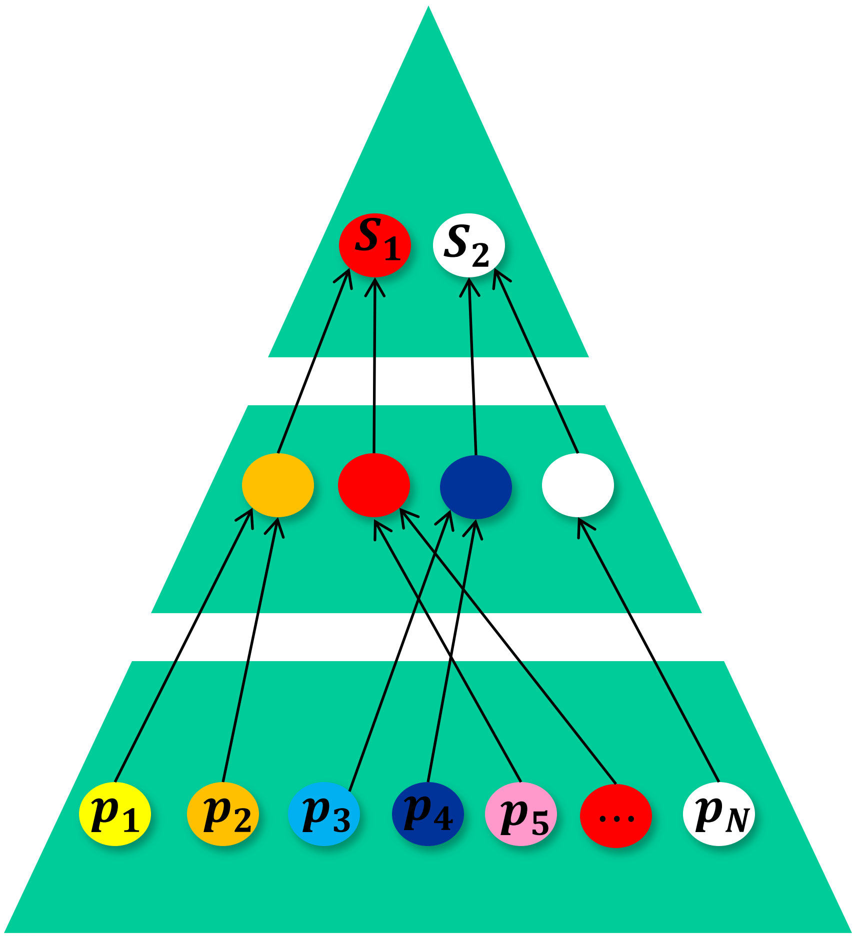

RUN-TIME

*System settings:*

- *Processor voltage*
- *Processor frequency*
- *Use of processing resources*
- *Code version*
- *etc...*

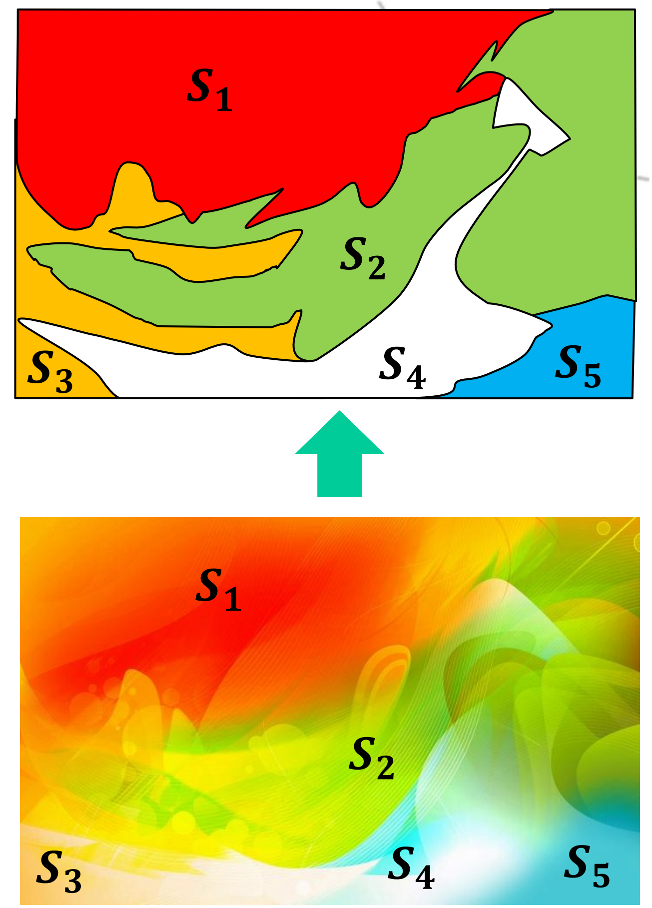
# Scenario clustering and characterization approaches

Bottom-up



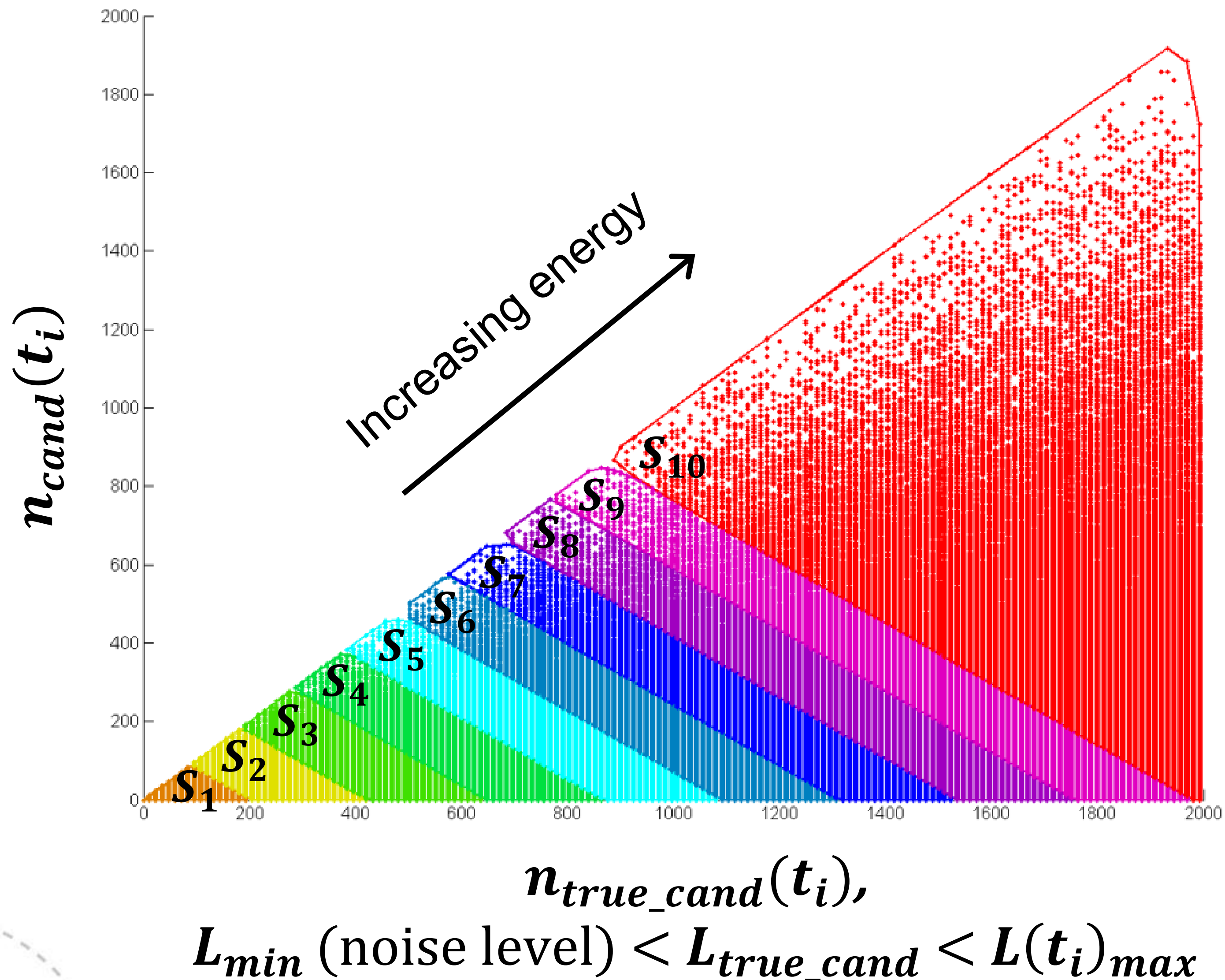

Small $N$

Top-down

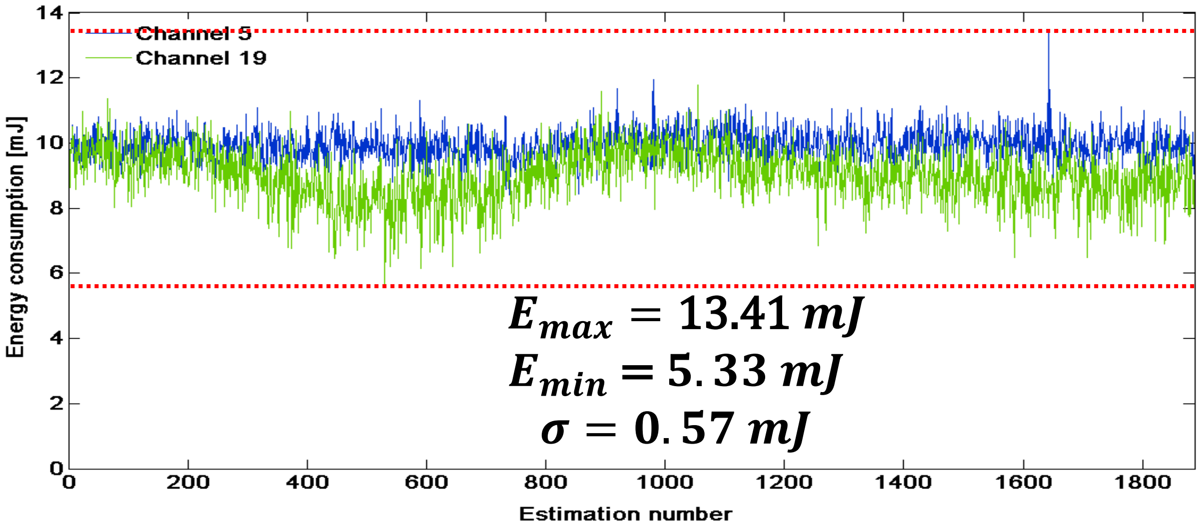



Large $N$

# System scenarios for STLmax calculation



# System scenarios for STLmax calculation




Energy consumption per channel on CoolBio DSP processor:

- Without system scenarios: $\mathbf{829}\ \frac{J}{channel}$
- With 10 system scenarios: $\mathbf{594}\ \frac{J}{channel}$
- Theoretically best input-adaptive solution: $\mathbf{567}\ \frac{J}{channel}$

(6 hours patient monitoring)

Thank you!

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