

# Live Demonstration: A Real-Time Bio-Mimetic System for Multichannel FES Control

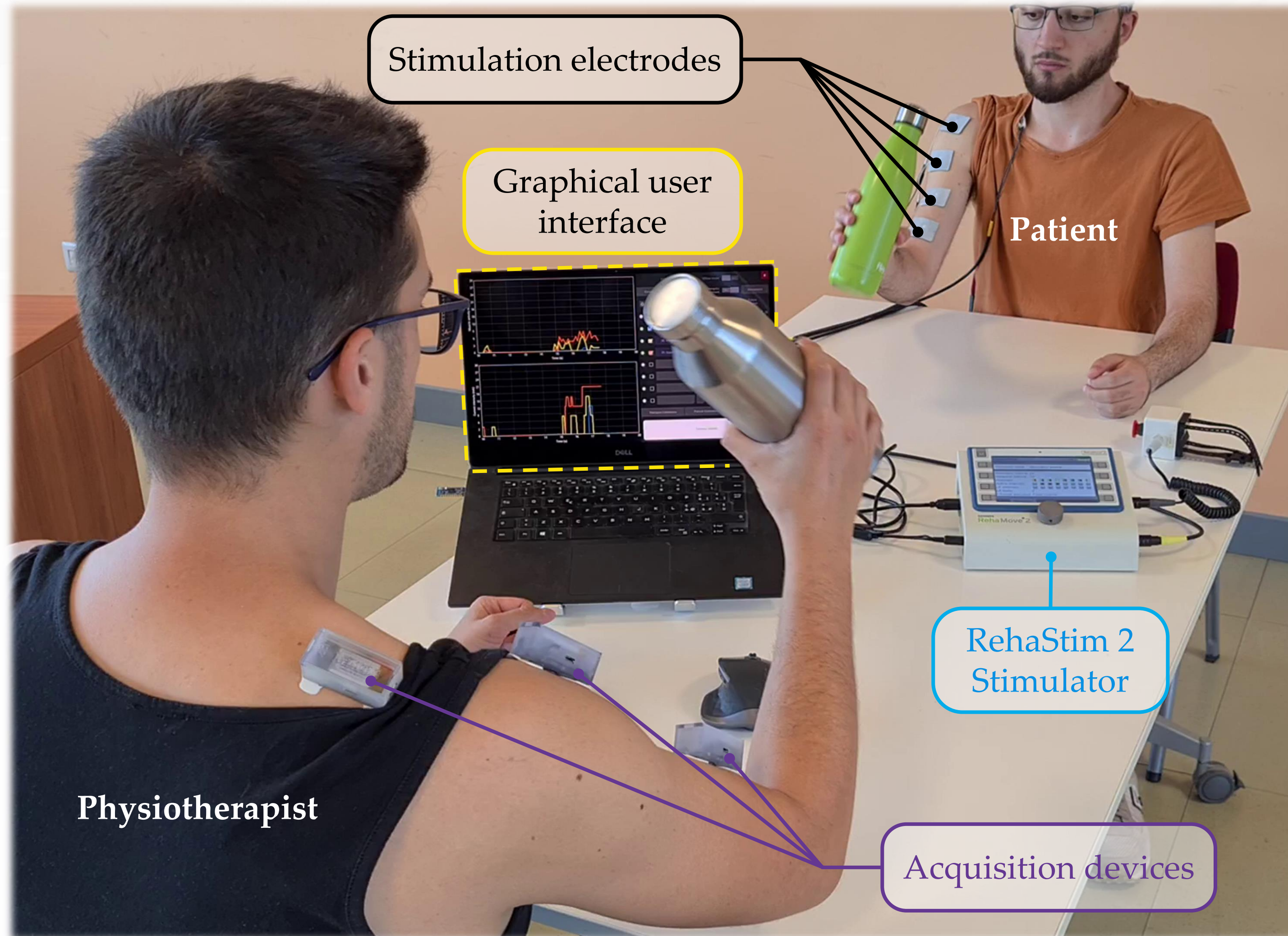
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Poster No. A2P-A6

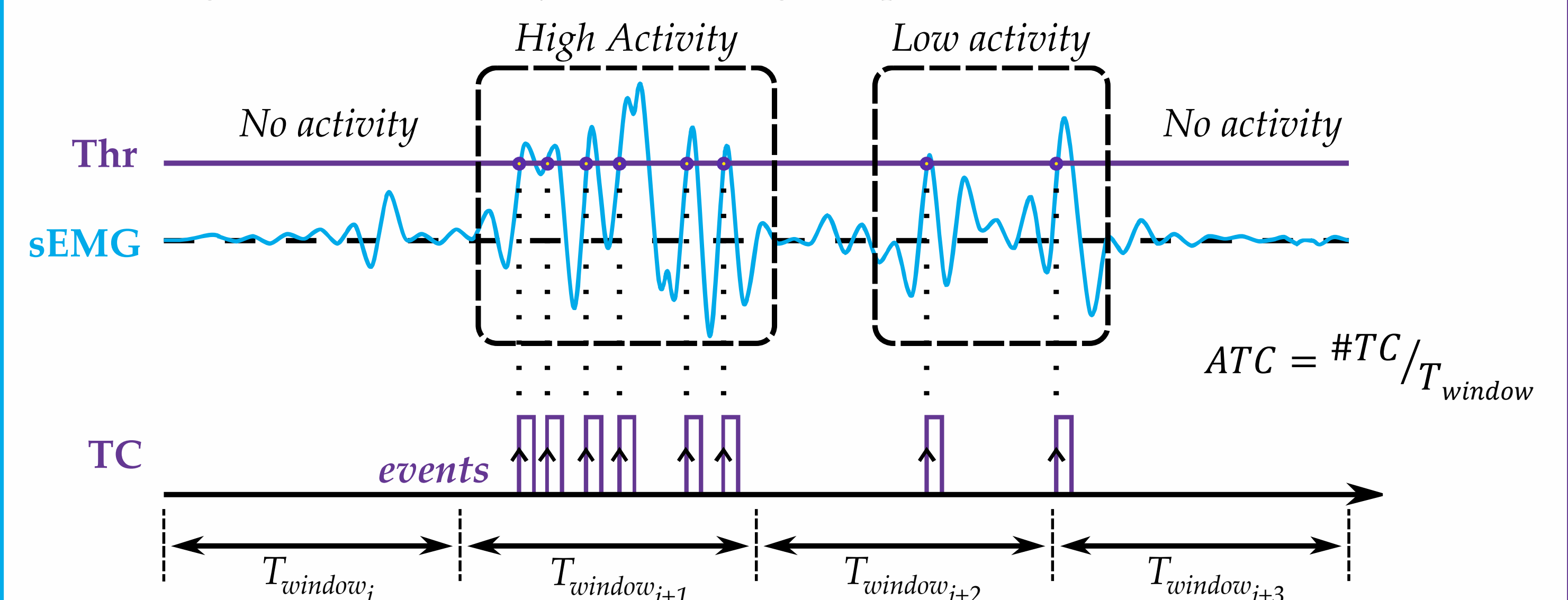
## Context and Motivation

**Functional Electrical Stimulation (FES)** therapy allows people suffering from neuromuscular disorders (e.g., spinal cord injuries, stroke, multiple sclerosis) to partially restore the compromised motor functions, thus improving their quality of life and social integration. Since recent literature studies confirm the benefits of actively modulating the FES parameters while stimulating coordinated muscle groups, here we present the latest implementation of our control system for FES, which, processing the muscular activity, enables a real-time definition of the stimulation patterns. Thanks to the implementation of a **custom feature extraction technique**, combined with an ad-hoc **per-subject multichannel calibration**, our system delivers **bio-mimetic FES profiles** suitable to sustain synergistic movements.

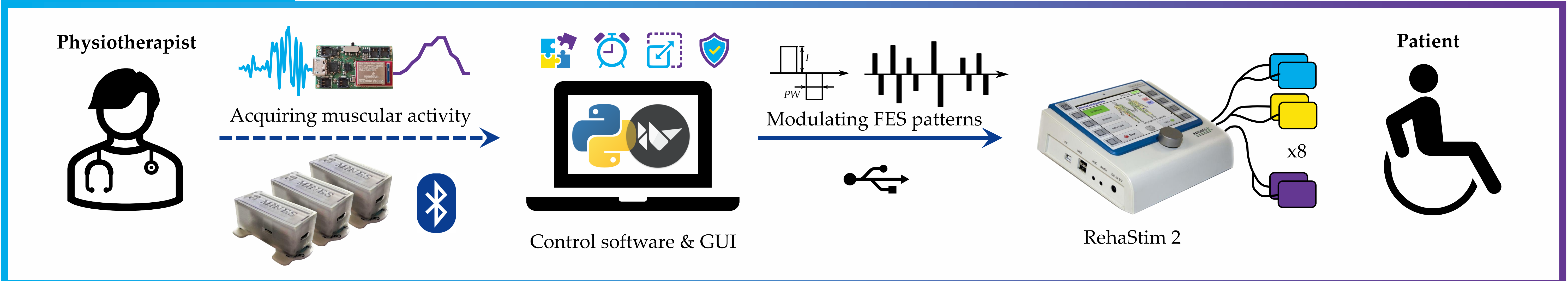


## Acquisition and Processing Methodology

The *event-driven Average Threshold Crossing (ATC)* technique is applied to the amplified and filtered **surface ElectroMyoGraphic (sEMG)** signal, describing the electrical activity of the skeletal muscles, to extract the informative content from the raw bio-signal. The *events* are identified with the rising Threshold Crossing (TC) occurrences. Their counting over an observation window (and the normalization w.r.t. the window duration) defines the **ATC parameter**. Since the demonstrated correlation with the exerted muscle force (0.95), the ATC can be used as a novel indicator for monitoring the muscle activity and defining FES parameters.



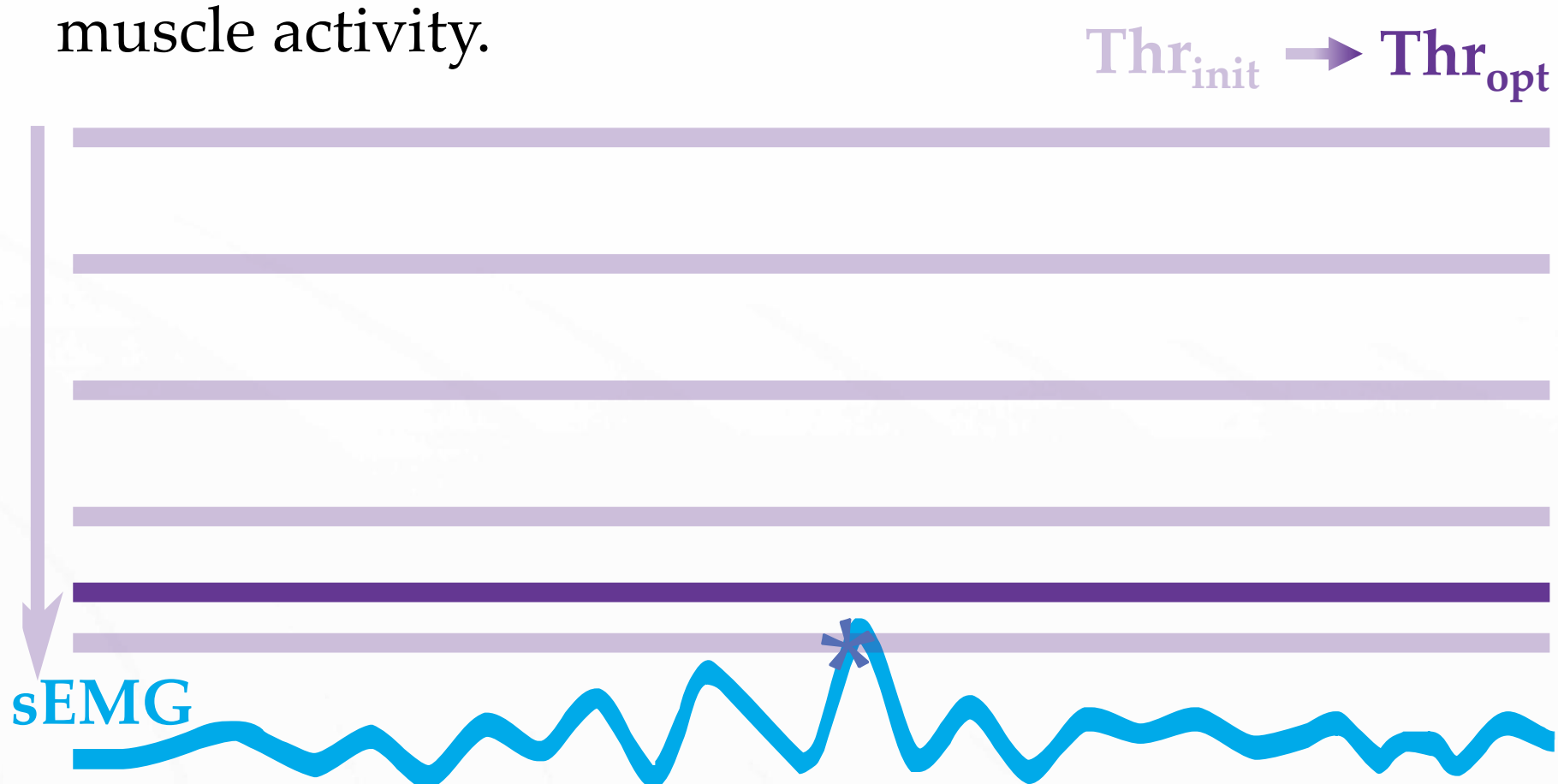
## System Architecture



## System Calibration

### Step 1 - Threshold calibration

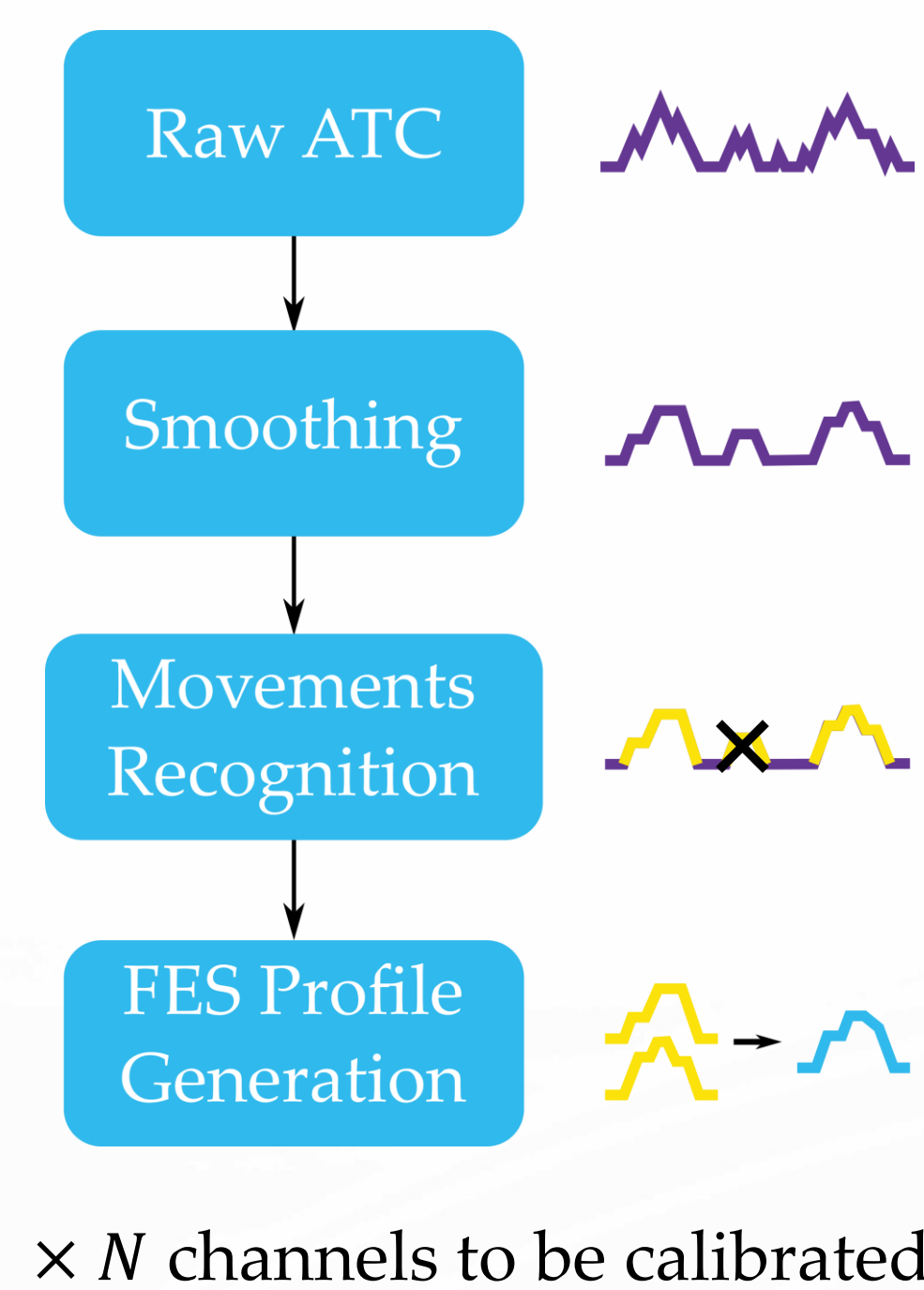
The thresholds for the TC signal generation are calibrated automatically for each board. The embedded algorithm searches for the baseline of the sEMG signal, during the muscle rest condition, in order to set the threshold just above it. Thus, it is possible to detect the events even with minimal muscle activity.



### Step 2 - Biomimetic FES profile extraction

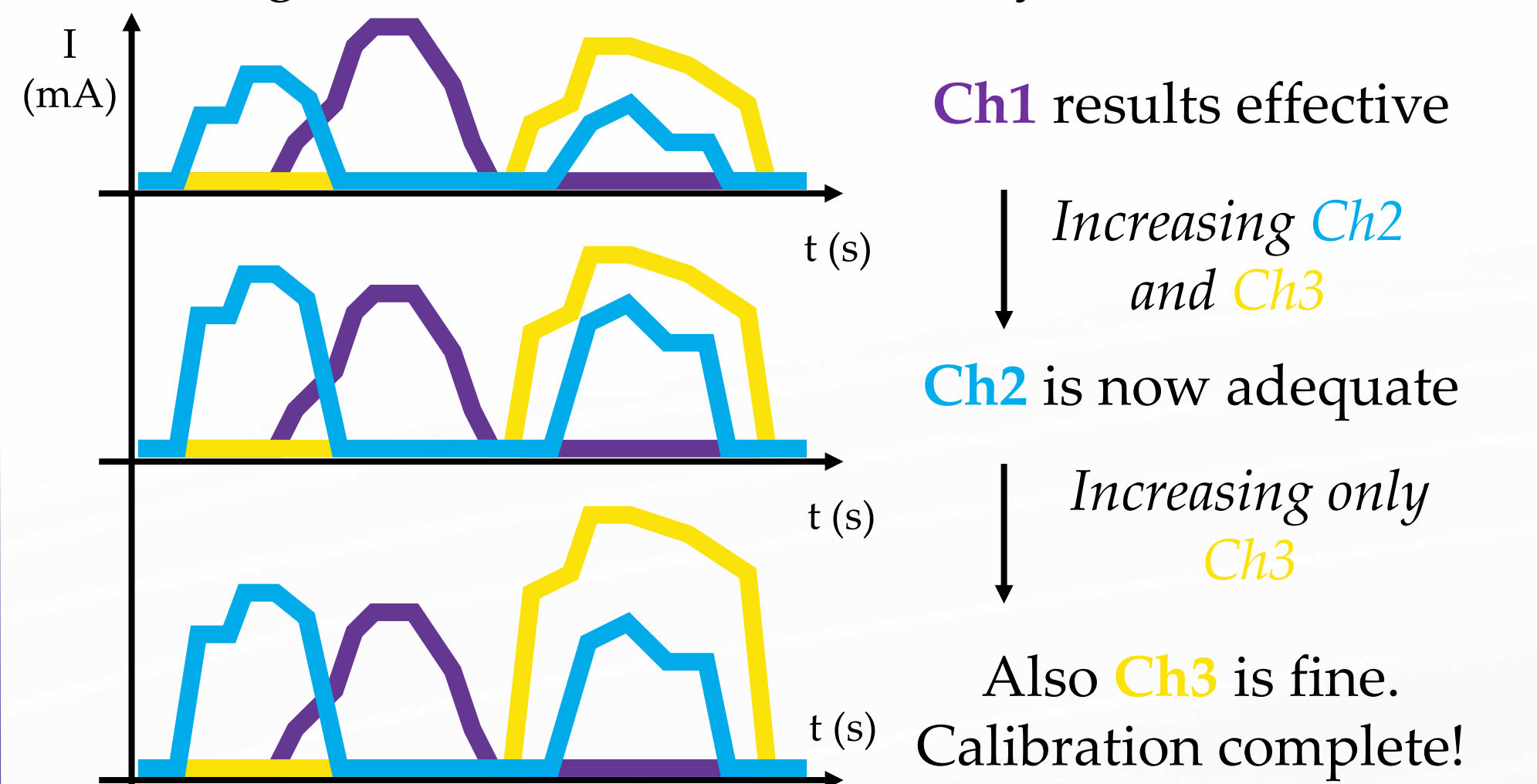
The Profile Extractor (PE) algorithm computes a multi-channel FES profile highly correlated with the muscular activity of the physiotherapist.

- Identification of the maximal ATC values of the physiotherapist
- Suitable to control coordinated multi-joint movement
- $\geq 4$  similar movements needed



### Step 3 - Patient calibration

The generated FES profiles are then applied to the patient to find the proper stimulation intensities able to elicit a functional movement. Each channel is calibrated in coordination with the others, adjusting its intensity according to the related muscle activity.



## Online Training

The fast computation of the FES patterns during the online control of the stimulation is achieved by mimicking the simple values association of a **Look-Up Table (LUT)** structure, whose parameters (input: ATC, output: pulse amplitude) are defined by the above calibration process.

- Median operation on the latest three ATC values:
  - **Stabilizer** of isotonic contraction (Ch 1)
  - **Noise-gateway** for spurious spikes (Ch 2)
  - **Smooth** (not painful and impulsive) FES application (Ch N)
- **Real-time processing** within 6 ms
- Perfect **match** between physiotherapist and patient muscular conditions

