ScuDo

Scuola di Dottorato ~ Doctoral School

WHAT YOU ARE,TAKES YOU FAR

XXXIV Cycle

Design of low power, miniaturized, wearable systems for the event-driven acquisition and processing of bio-medical signals

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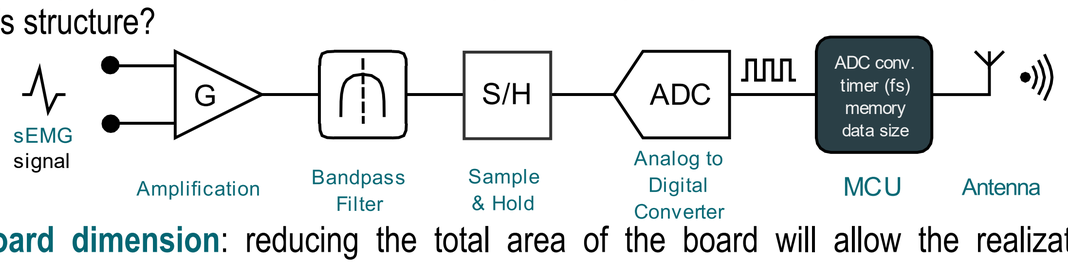
Supervisors: Prof. Danilo Demarchi and Ph.D. Paolo Motto Ros

Research context and motivation

- The **surface ElectroMyoGraphic** (**sEMG**) signal, which represents the electrical activity of the skeletal-muscle system, allows the clinicians to assess the physical condition of subjects affected by neuro-muscular disorders (e.g., post-stroke, SCI or hemiplegic).
- The bio-electronic challenges concerning the development of an sEMG detecting system cover the main target of the **IoT** scenario: **portable** and **wearable** device, **ultra low power** performance, **low cost** manufacturing.

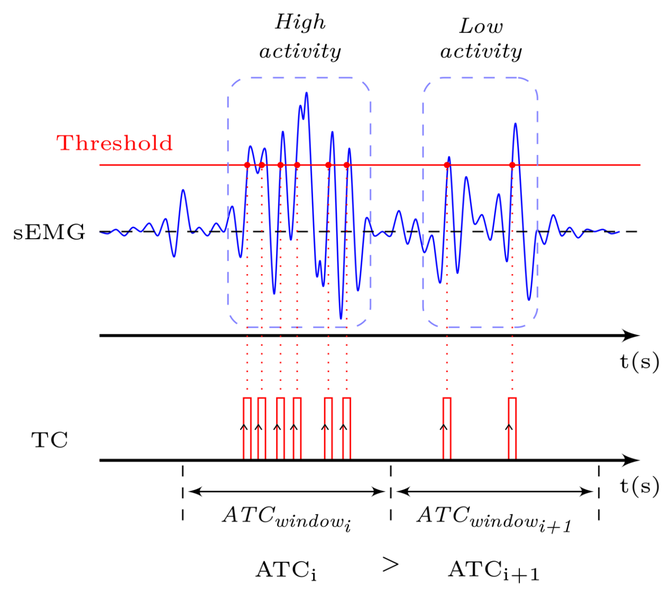
Addressed research questions/problems

- The main **constraints** and **difficulties** in developing such a system are:
  - **Bio-signal front-end**: amplification stage, filtering stage, S&H and ADC. How to simplify this structure?



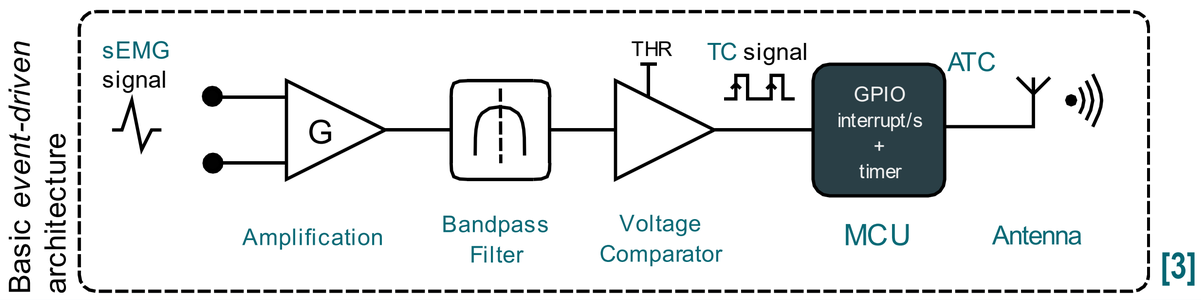
  - **Board dimension**: reducing the total area of the board will allow the realization of wearable device.
  - **Data dimension**: the data amount to be stored, wireless transmitted and processed affects significantly the duration of battery-device.
  - **Wireless protocol**: which one is the most efficient considering the type of data?
  - **Synchronization**: how to synchronize each acquisition node with the proper accuracy?
  - **Power supply**: battery type vs. power consumption.

Novel contributions



Average Threshold Crossing (ATC):

- Event-driven bio-inspired technique
- TC as *quasi-digital* signal
- **ATC** parameter: $\frac{\#TC_{events}}{ATC_{window}}$
- **Advantages:**
  - ADC **removal**
  - HW and SW **complexity reduction**
  - limitation of transmitted and processed data
  - on-board **feature extraction** process



[3]

External Research Activity

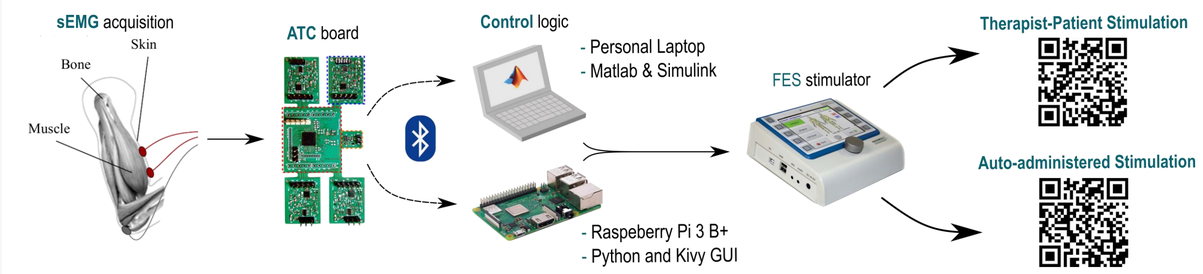
- ***MITOR/SISTER* project** – Visiting Ph. D. student at Motion Analysis Lab (MAL), Spaulding Rehabilitation Hospital, Boston (MA).
- *Erasmus + European **MECA*** project
- *International Master Degree Education in Nanoelectronics in Asian Universities (**NanoEI**)*

List of attended classes

- 01RISRV – Public Speaking (03/07/2019, 1 CFU)
- 01QZTRR – Progettazione di dispositivi medici per la chirurgia (17/07/2019, 4 CFU)
- 01SWPRV – Time Management (18/07/2019, 1 CFU)
- 01SFURV – Programmazione scientifica avanzata in matlab (-)
- 01QEZRV – Sviluppo e gestione di sistemi di acquisizione dati (-)
- 01RGGRV – Telemedicine and Distributed Healthcare (-)

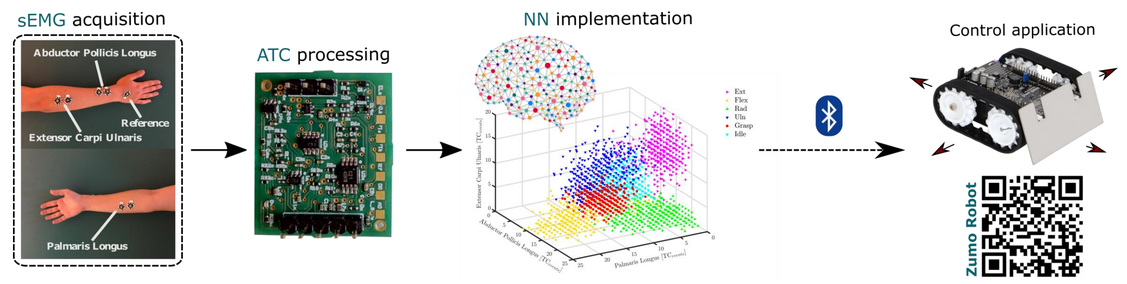
Adopted methodologies

1 Control of the Functional Electrical Stimulation [2, 3, 5, 7]



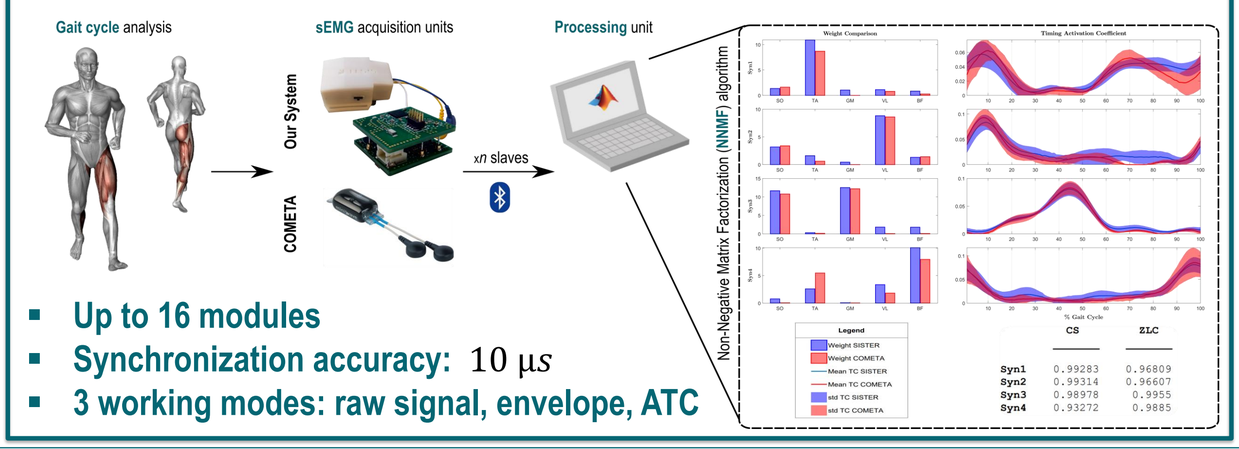
- **Good movement reproducibility**
- **Data reduction:** $2\ kB/s$ (sEMG) vs. $8\ B/s$ (ATC)
- **Power consumption ($\sim 20\ mW$):** 4 ATC chs. vs. 1 sEMG ch.
- **Portability and versatility**

2 Gesture Recognition [1, 6, 8]



- **6 gestures vs. 3 electrode chs.**
- **Latency:** $8.5\ ms$ (classifier) / $268.5\ ms$ (control)
- **Classifier accuracy:** $96.3\ \%$
- **Power consumption:** $0.8\ mW$ (MCU) / $2.9\ mW$ (system)

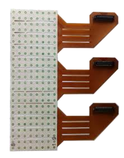
3 Muscle Synergies Analysis [4]



- **Up to 16 modules**
- **Synchronization accuracy:** $10\ \mu s$
- **3 working modes: raw signal, envelope, ATC**

Future work

- Replace bipolar differential acquisition with **matrices**
- Move to the use of **dry electrodes**
- Equip the acquisition board with **UWB** wireless transmission
- Extract different features from the TC signal
- Study the feasibility of the event-driven processing of the **EEG signal**
- Build-up an **event-based system** suitable for different bio-signals



Submitted and published works

- [1] Sapienza, S., Motto Ros, P. , Fernandez Guzman, D. A., Rossi, F., Terracciano, R., Cordedda, E. and Demarchi, D., "*On-Line Event-Driven Hand Gesture Recognition Based on Surface Electromyographic Signals*", 2018 IEEE International Symposium on Circuits and Systems (ISCAS), Florence, 2018, pp. 1-5, **(Published)**
- [2] Rossi, F., Motto Ros, P., and Demarchi, D., "*Live Demonstration: Low Power System for Event-Driven Control of Functional Electrical Stimulation*", 2018 IEEE International Symposium on Circuits and Systems (ISCAS), Florence, 2018, pp. 1-1. **(Published)**
- [3] Rossi, F., Motto Ros, P., Sapienza, S., Bonato, P., Bizzi, E., and Demarchi D. , "*Wireless Low Energy System Architecture for Event-Driven Surface Electromyography*", In: Saponara S., De Gloria A. (eds) Applications in Electronics Pervading Industry, Environment and Society. ApplePies 2018. Lecture Notes in Electrical Engineering, vol 573. Springer, **(Published)**
- [4] Tuoheti, A., Rossi, F., Motto Ros, P., Sapienza, S., Bonato, P., Bizzi, E. , and Demarchi, D, "*Wearable Wireless sEMG System for Long-term Muscle Synergies Monitoring*", 51th Annual meeting of the Società Italiana di Elettronica (SIE), Rome, 2019. **(Published)**
- [5] Rossi, F., Rosales, R. M., Motto Ros, P., and Demarchi D. , "*Real-Time Embedded System for Event-Driven sEMG Acquisition and Functional Electrical Stimulation Control*", Applications in Electronics Pervading Industry, Environment and Society. ApplePies 2019. **(Accepted)**
- [6] Mongardi, A., Rossi, F., Motto Ros, P., Sanginario, A., Ruo Roch, M., Martina, M. and Demarchi D. , "*Live Demonstration: Low Power Embedded System for Event-Driven Hand Gesture Recognition*", Biomedical Circuits and Systems Conference (BioCAS), Nara, 2019. **(Accepted)**
- [7] Rossi, F., Motto Ros, P., Cecchini, S., Crema, A., Micera, S. and Demarchi D. , "*An Event-Driven Closed-Loop System for Real-Time FES Control*", 26th IEEE International Conference on Electronics Circuits and Systems (ICECS), Genoa, 2019. **(Accepted)**
- [8] Mongardi, A., Motto Ros, P., Rossi, F., Ruo Roch, M., Martina, M. and Demarchi D., "*A Low-Power Embedded System for Real-Time sEMG based Event-Driven Gesture Recognition*", 26th IEEE International Conference on Electronics Circuits and Systems (ICECS), Genoa, 2019. **(Accepted)**

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