Giusy Spacone

PhD Researcher – Wearable Multimodal Neuromotor Interfaces at the Edge

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Research Profile

I am a PhD researcher at the Integrated Systems Laboratory at ETH Zurich. My research focuses on **next-generation wearable, multimodal neuromotor interfaces** for novel human-machine interaction strategies. Bringing together surface electromyography (sEMG), A-mode ultrasound (US) and inertial (IMU) sensing, I work across the full pipeline: from wearable **form-factor** development and system integration to **machine learning** for physiological signal decoding, **on-device deployment** and validation through **human-subject studies**, towards end-to-end, user-centered solutions for real-world use cases. My two main application domains are **hand-gesture recognition and continuous kinematic tracking**, and **silent-speech interfaces**.

Deep learning • Edge AI • Biosignal processing • Wearables • Human–machine interfaces • Sensor fusion • Embedded firmware

Technical Skills and Tools

Machine learning & signal processing	Python, PyTorch, scikit-learn, SciPy; physiological signal processing, time-series classification and regression, multimodal sensor fusion, CNNs and transformer-based sequence models, fine-tuning for cross-day recalibration
Embedded AI	ARM Cortex-M (nRF52), RISC-V (GAP9); LiteRT / TensorFlow Lite and research deployment frameworks, INT8 quantization, embedded inference, power profiling
Embedded firmware	C, Zephyr RTOS, ESP-IDF
PCB design	KiCad, Altium
Wearable sensing	sEMG, A-mode US, IMU; wearable system design, sensor integration
Experimental research	Human-subject study design, ethics applications

Key Research Projects

ETH Zurich, Integrated Systems Laboratory • Professor: Prof. Luca Benini • Co-advisor: Dr. Andrea Cossettini

Hand-gesture recognition and kinematic regression via wearable sEMG, A-mode US and IMU fusion

Continuous hand–wrist tracking is key to enabling natural human–machine interaction, yet challenges remain to ensure robustness across users and sensor repositioning. This research combines established modalities (sEMG, IMU) with A-mode US to capture complementary muscle information for robust, low-power kinematic tracking and gesture recognition, towards reliable real-time interaction across multiple days.

- **Wearable A-mode US for kinematic tracking.** *Contributions:* designed a four-transducer US armband and interfaced it with the WULPUS acquisition system (WULPUS); integrated optical motion-capture system and instrumented glove for ground-truth acquisition; conceived and led the data collections; developed XGBoost and CNN regression models, quantized (INT8) and deployed both on nRF52. *Results:* 3-DoF regression | 5 subjects over 9 sessions | XGBoost | inter-session RMSE 11.1°; extended to 23-DoF regression | 2 subjects | 11k-parameter CNN | 29.1 ms inference on the nRF52 MCU, <35 mW power consumption for sensing, inference and BLE result transmission.
- **Concurrent EMG + US fusion.** *Contributions:* designed a flexible EMG PCB and wearable armband interfacing with the BioGAP (BioGAP) acquisition system; implemented firmware-level synchronization for concurrent EMG and US data acquisition; designed and led data collections; developed a CNN-based EMG–US late-fusion architecture. *Results:* 23-DoF regression | inter-session RMSE 10.6° vs. 12.0° (EMG only) and 13.1° (US only).
- **US + IMU for real-time VR interaction.** Moving from offline tracking to online control, US and IMU sensing have been combined for interaction in VR. *Contributions:* conceived and led multi-day data collections for concurrent hand-pose and forearm-position estimation; developed US–IMU late-fusion CNNs and personalized recalibration strategies; implemented the real-time inference pipeline and its integration with a Unity-based VR environment. *Results:* hand-pose and forearm-position classification | 5 subjects over 5 days | late-fusion CNN | 80% / 77% inter-session accuracy; 88–96% online VR success after 5 min of recalibration. Demo video

Featured publications:

2026 **Spacone, G.** et al. "A wearable multimodal ultrasound + inertial system for real-time virtual reality interaction." IEEE International Conference on Systems, Man, and Cybernetics (SMC), 2026. **Best Conference Paper Award.** Demo video Open access

2026 **Spacone, G.** et al. "Toward whole hand and wrist kinematic tracking with a wearable A-mode ultrasound probe." IEEE Open Journal of Ultrasonics, Ferroelectrics, and Frequency Control, 2026. IEEE Open access

2025 **Spacone, G.** et al. "Wearable and ultra-low-power fusion of EMG and A-mode US for hand-wrist kinematic tracking." IEEE Biomedical Circuits and Systems Conference (BioCAS), 2025. IEEE Open access

2024 **Spacone, G.** et al. "Tracking of wrist and hand kinematics with ultra-low-power wearable A-mode ultrasound." IEEE Transactions on Biomedical Circuits and Systems, 2024. IEEE

In progress: Distributed EMG + US + IMU fusion for VR and robotic control.

Silent-speech interfaces via wearable sEMG and multimodal fusion

Silent-speech interfaces decode speech-related intent from physiological signals, enabling private and accessible communication; however, existing approaches rely on obtrusive sensing and struggle with robustness across sessions. This research area explores unobtrusive, wearable interfaces with on-device processing. *Contributions:* conceptualized SilentWear, a fully wearable, dry-electrode textile sEMG neckband built around the BioGAP platform; conceived and conducted multi-day, multi-

subject studies with vocalized and silent speech recordings; developed SpeechNet, a compact 15k-parameter CNN for edge deployment, together with a personalized fine-tuning strategy for inter-session robustness. *Results:* 8-command recognition | 4 subjects | SpeechNet | 84.8% / 77.5% accuracy (vocalized / silent, aggregated evaluation); fine-tuning recovers >10 percentage points of accuracy lost to repositioning within <10 min of personalization; 2.47 ms inference at the edge (GAP9).
SilentWear repository SilentWear dataset

Featured publications:

2026 **Spacone, G.** et al. "SilentWear: An ultra-low-power wearable system for EMG-based silent speech recognition." IEEE Sensors Journal, 2026. IEEE Open access

2025 Meier, F., **Spacone, G.**, et al. "A parallel ultra-low-power silent speech interface based on a wearable, fully-dry EMG neckband." IEEE SENSORS, 2025. Open access

In progress: EMG, EEG and audio fusion for continuous speech recognition.

Foundation models for edge deployment

Foundation models (FMs) can learn transferable representations from physiological signals, reducing the need for task-specific models and labeled data; however, variability across acquisition systems, subjects and tasks challenges generalization, and computational cost limits wearable deployment. This research investigates compact FMs bridging transferable representation learning and edge inference. *Contributions:* conceived TinyMyo, the first EMG FM at the edge, and defined its research direction, including dataset unification, the pre-training framework and multi-task downstream evaluation; supervised its development and experimental validation within a Master's thesis. *Results:* the 3.6M-parameter transformer backbone is evaluated on gesture recognition (NinaPro DB5, UCI-EMG, EPN-612, Generic Neuromotor Interface by Meta), kinematic regression (NinaPro DB8) and silent speech (Gaddy). Deployed on GAP9, where a 1.9M-parameter variant achieves 89 ms inference on 1-s windows.

Featured publications:

2026 Fasulo, M., **Spacone, G.**, et al. "TinyMyo: A tiny foundation model for flexible EMG signal processing at the edge." IEEE Transactions on Biomedical Engineering, 2026. IEEE Open access

In progress: Foundation models for A-mode US at the edge.

Full publication list on Google Scholar.

Teaching, Mentoring & Academic Service

Teaching Assistant • *Wearable Ultrasound (P&S); Clinical & Movement Biomechanics • ETH Zurich* 2022 – present

Primary supervisor of 15+ student research projects • *defining research directions • ETH Zurich* 2024 – present

Workshop | A-mode US at the edge: hands-on deployment with open-source tools • *IEEE Central and Eastern European Ultrasonics Symposium | Warsaw, PL* 2026

Reviewer • *IEEE Transactions on Human-Machine Systems; Nature Communications; NeurIPS workshop*

Awards

Best Conference Paper Award • *IEEE International Conference on Systems, Man, and Cybernetics (SMC)* 2026

Best Freshman Prize • *Politecnico di Milano – awarded to the top first-year students* 2019

Alfiere del Lavoro • *Honor from the President of the Italian Republic (25 students nationwide)* 2018

Education

Ph.D., Information Technology & Electrical Engineering (D-ITET)
ETH Zurich, Integrated Systems Laboratory | Zurich, CH Jun 2024 – present (exp. Sep 2028)

M.Sc., Biomedical Engineering (Major: Bioelectronics & Biosensors)
ETH Zurich | Zurich, CH Sep 2021 – Apr 2024
GPA **5.74 / 6.0** • **Master's thesis:** wearable armband for concurrent ultrasound–EMG acquisition (Prof. L. Benini).

B.Sc., Biomedical Engineering
Politecnico di Milano (PoliMi) | Milan, IT Sep 2018 – Jul 2021
Grade **110 / 110 cum laude** • **Bachelor's thesis:** GSR signal analysis for human–machine interaction (NearLab).

Industry Experience

Rotational Internship – Electronics, R&D and Data Science
Nanoleq | Zurich, CH Feb 2023 – Jul 2023
Rotated across the electronics, R&D and data-science teams: PCB design and firmware for automated lithium-battery life-cycle testing with data-analysis pipelines; defined experimental protocols for ESD characterization of wearable biosensing textiles; designed and conducted a multimodal stress-monitoring study (ECG, respiration, EDA), from protocol definition to data analysis.

Beyond Research

Leadership & Associations

2023 – present Founder & President, Swiss Italian Society (SIS) – sis-zh.com

2024 – present Head of External & Institutional Relations, United Italian Society – Switzerland

2020 – 2024 Lead the Future mentoring program – mentee and ETH Zurich ambassador

2018 – 2021 Student representative, Biomedical Engineering, Politecnico di Milano

Languages Italian (native), English (C1), German (B1)

Soft skills Leadership & team building; mentoring (15+ supervised student projects); communication (workshops, talks, journalism); resilience & time management (former competitive alpine skier, now running & cross-training)