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DESIGN AND ASSESSMENT WEARABLE ROBOTICS

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Sensor fusion for a robust hand prosthesis and exoskeleton control system: A concept proposal

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Introduction:

Depending on age, prosthesis type, and the survey, 24–70% of users eventually abandon their prosthesis [1]. Beyond mechanical design, user acceptance largely depends on the control system's ability to accurately interpret movement intention.

Most commercial systems rely on surface electromyography (sEMG), which faces serious bottlenecks:

- signal degradation due to muscle fatigue,
- inability to clearly differentiate between surface and deep muscles,
- not being robust in non-isometric cases.

In this paper, our three different modalities are uncovered, and we consider the conceptual possibility of integration.

Methods:

High density surface electromyography (HD-sEMG,[2]):

- analogue, 64-channel device
- aim at: hw+sw system to differentiate between surface and deep muscles on the forearm + decompose in non-isometric case
- partial results already on FDS-FDP differentiation

Amplitude-mode ultrasound (A-mode US, [3], Fig. 2):

- 8-channel prototype with custom firmware, modular, programmable frequency, time-compensated gain
- aim at: hw+sw system to measure muscles on anatomically relevant locations

Near-infrared spectroscopy (NIRS, [4],[5], Fig. 3):

- 12x3 channels (12 PDs, 3 LEDs)
- topographically sensitive on muscle oxygenation
- aim at: hw+sw system as additional modality to recognize fatigue

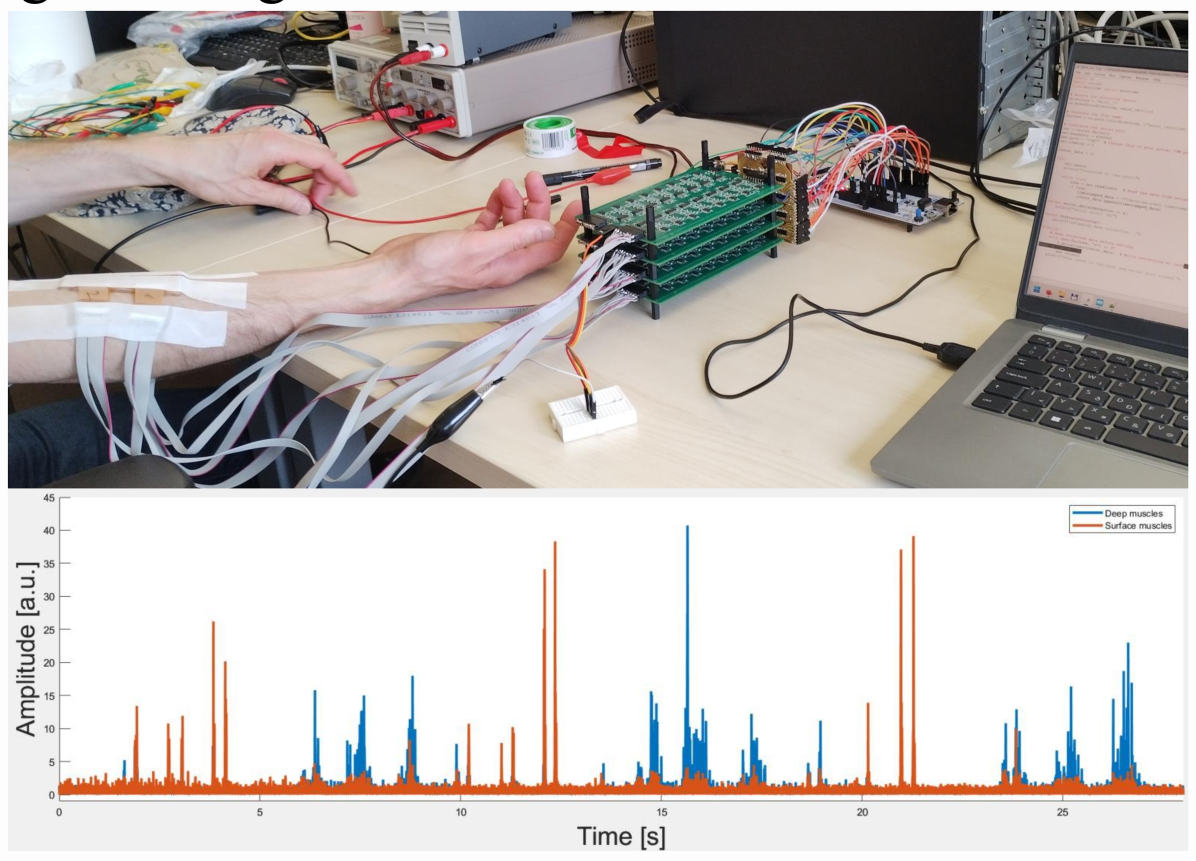

Fig.1. Top: 64-channel sEMG measurement setup.
Bottom: separation of surface and deep forearm muscle activity.

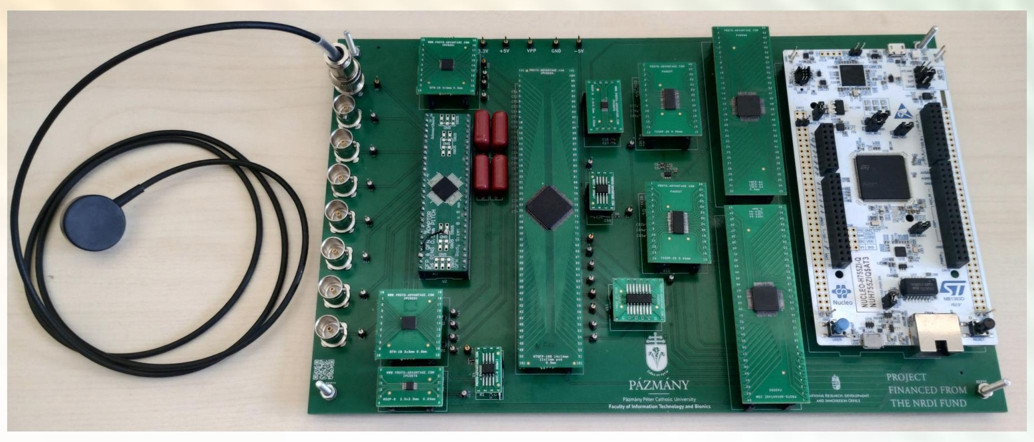

Fig.2. 8-channel, amplitude-mode ultrasound

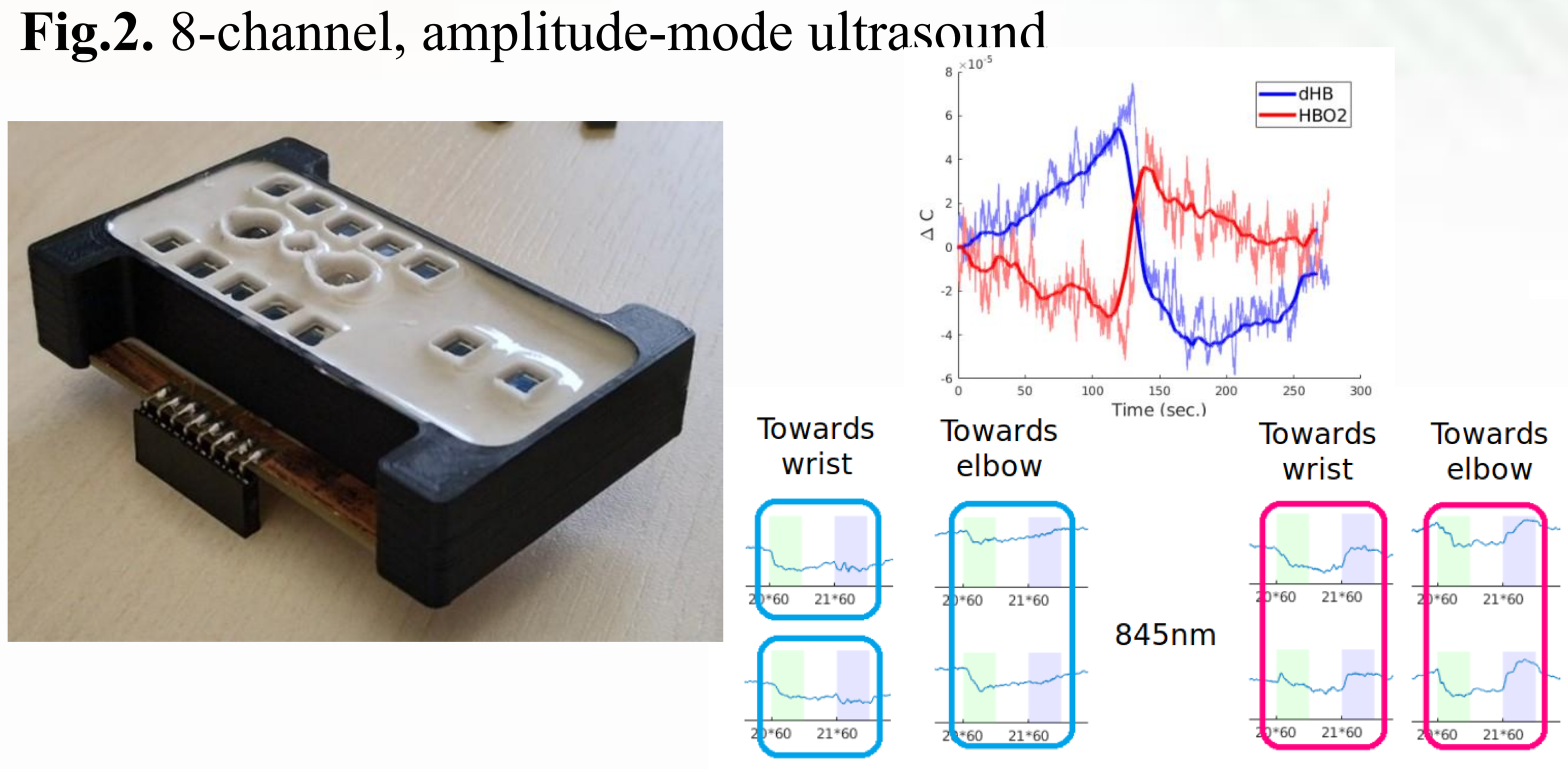

Fig.3. Left: Near-infrared spectroscopy device. Top-right: occlusion experiment. Bottom-right: comparison of raw waveforms to support topographical sensitivity.

Conceptual points to integration:

Miniaturization & Placement

- Optimal density and minimal size are crucial.
- Limits: sensor tech constraints and poorer SNR in smaller elements.

Interference between modalities

- Sensors must not affect each other.
- Potential EM noise: sEMG arrays as antennas, blinking LEDs, A-mode US effects.

US-NIRS Interaction

- A-mode US may heat tissue → dilated arteries → NIRS signal noise.
- Mitigation: low-energy US, small transducers, smart activation cycles.

Sensor Integration

- US+EMG coexistence is feasible.
- NIRS needs direct optical contact.
- Use flexible PCBs, transparent gels, and anatomically guided placement/timing.

Design Considerations

- Human-centered, anatomy-driven layouts enhance signal clarity.

Soft Exoskeleton Application [6]

- Harnesses cause skin displacement, affecting sensor stability.
- Solution: place sensors and fixations in separate regions.

Forearm as Ideal Site: minimizes actuation interference & gives stable sensor-skin interface.

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