Initial Steps with an Array-like Near Infrared Spectroscopy Device for Upper Limb Measurements

COPENHAGEN
IEEE EMBS IEEE Engineering Medicine & Biology Society
47TH ANNUAL International Conference of the IEEE Engineering in Medicine and Biology Society

Poster No. Mon-291

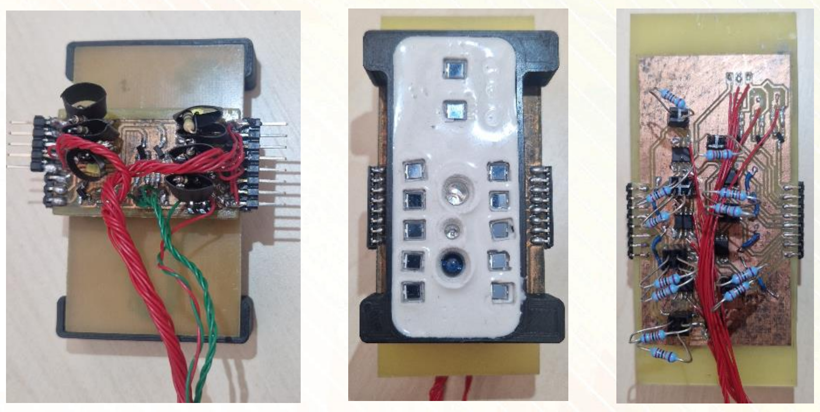
*Alexis Gibert[1], Sándor Földi[2], **Miklós Koller**[2]*
[1] Faculté des Sciences et d'Ingénierie, Université Paul Sabatier, Toulouse, France
[2] Faculty of Information Technology and Bionics, Pázmány Péter Catholic University, Budapest, Hungary

INTRODUCTION

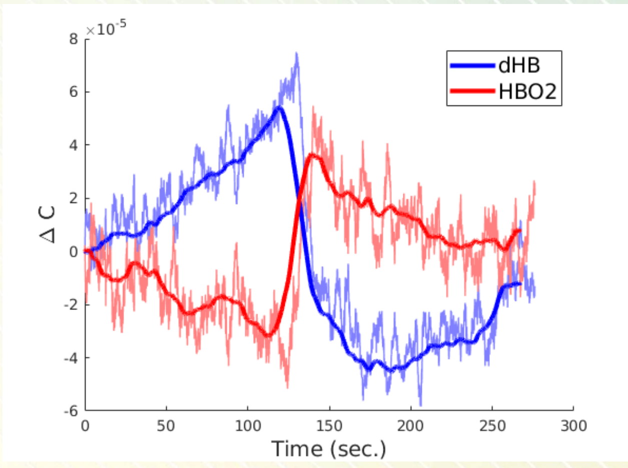
- Depending on age, prosthesis type, and the survey, **24–70% of users eventually abandon their prosthesis** [1]. Beyond mechanical design, **user acceptance** largely **depends on the control system's ability to accurately interpret movement intention**.
- Most commercial systems rely on **surface electromyography (sEMG)**, which faces a serious bottleneck: **signal degradation due to muscle fatigue**. This loss of reliability impairs system robustness in real-world conditions.
- To overcome this, we introduce a **second physiological modality: near-infrared spectroscopy (NIRS)**, which **detects local changes in blood oxygenation**. As hemodynamic signals are independent of fatigue, NIRS provides a stable and complementary control input.
- Our goal is to develop a custom NIRS sensor system to support more robust prosthetic control, building in part on the approach proposed in [2].

METHODS – HARDWARE SYSTEM

- Custom-built NIRS device with:
  - **3 LEDs** (720, 810, 845 nm)
  - **12** near-infrared **photodiodes**
  - **STM32**-based **controller** board
- Two sensor board versions tested:
  - V1 – **voltage-drop resistor readout**
  - V2 – **transimpedance amplifier** (TIA) **readout**
- LEDs are driven by bipolar transistors, controlled by the STM32 microcontroller.
- Photodiode signals are read out via analog circuitry and digitized for PC-side processing.
- Relative hemoglobin concentrations are calculated using the **Modified Beer–Lambert Law** (MBLL).



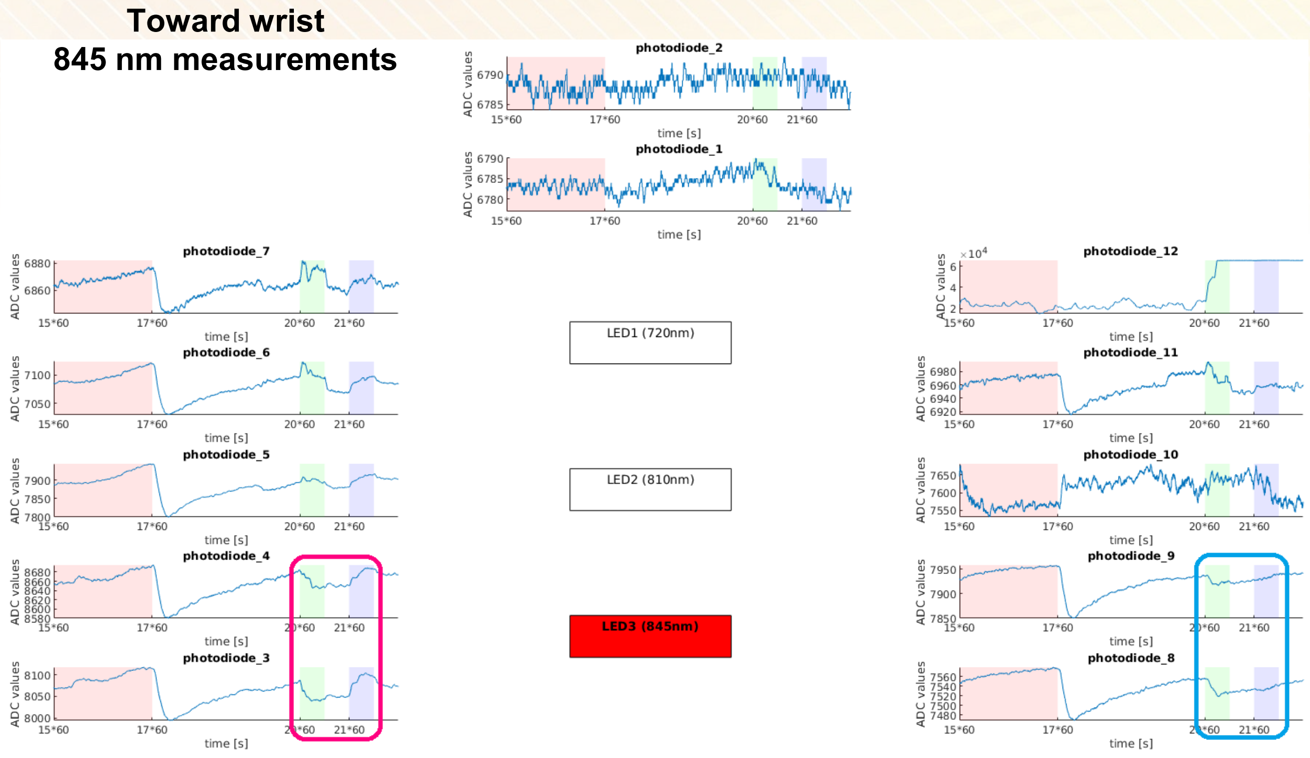
V1 sensor panel V2



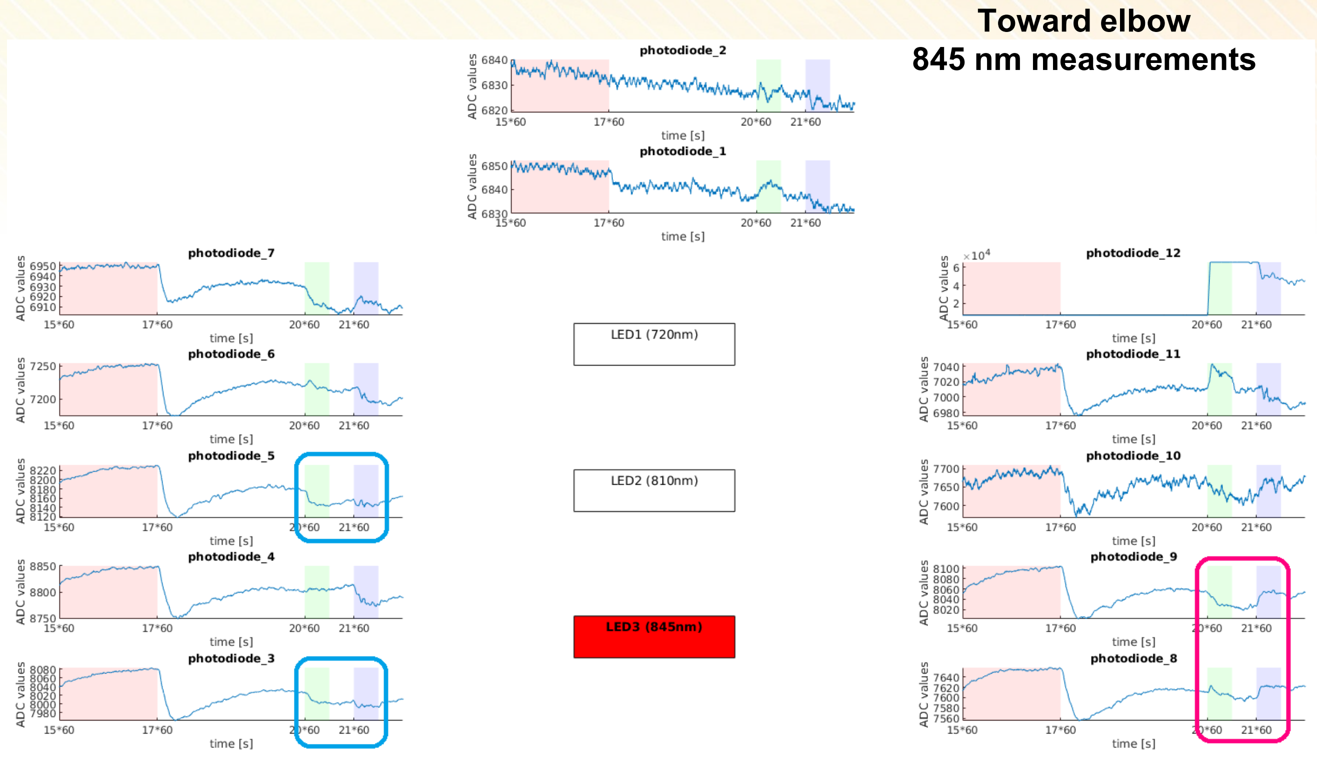
MEASUREMENTS

- **Sensor** longitudinally **over the Flexor Digitorum Superficialis** (FDS) **muscle** (anterior forearm), aligned with muscle fibers.
- Two placements tested: device heading **toward the wrist** and **toward the elbow**, to evaluate topographic sensitivity.
- **Protocol steps**:
  - 15 min rest for system warm up
  - 2 min occlusion on upper arm (blood flow blocked)
  - 3 min rest
  - 4 × 30 s activations: ring and middle finger movements, alternating with rest
- One subject (co-author) performed all trials with voluntary consent, lab conditions.

Toward wrist
845 nm measurements



Toward elbow
845 nm measurements



Alexis Gibert at alexis.gibert@univ-tlse3.fr
Sándor Földi, PhD at foldi.sandor@itk.ppke.hu
Miklós Koller, PhD at koller.miklos@itk.ppke.hu
The authors would like to thank the contributions of András Lenkovics and Réka Kiss.

PÁZMÁNY
Pázmány Péter Catholic University
Faculty of Information Technology and Bionics

References
[1] D. Piscitelli, M. Beghi, M. Bigoni,S. Diotti, C. Perin, F. Peroni, M. Turati, N. Zanchi, M. Mazzucchelli, and C. M. Cornaggia, ``Prosthesis rejection in individuals with limb amputation: a narrative review with respect to rehabilitation,'' Rivista di psichiatria, vol. 56, no. 4, p. 175--181, 2021
[2] F. Xie, S. Huang, T. Miao, S. He, Z. Lin, and L. Xie, ``Development of a wireless multichannel near-infrared spectroscopy sensor system for monitoring muscle activity,'' IEEE Sensors Journal, vol. 22, no. 23, pp. 22714–22724, 2022, doi: 10.1109/JSEN.2022.3216351

Acknowledgments
This work was supported by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the TKP2021-NKTA funding scheme (project no. TKP2021-NKTA-66).

National Research, Development and Innovation Office Hungary
PROJECT FINANCED FROM THE NRDI FUND