Title: Advanced myoelectric control of distal joints		
Supervisor Co- Supervisor	Name Surname	Aoustin Yannick
	Laboratory/Team	LS2N/REV
	Number of theses in progress	2 (one co-tutelle 50%/one institution contract 50%)
	Name Surname	Jozina De Graaf (PU)
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	Number of theses in progress	3 (2 à 100%, 1 à 50%), soutenances prévues fin de l'année
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	Laboratoire/Équipe	LS2N/SIMS
	Number of theses in progress	2 (à 30%)
	Graduate School	ED MaSTIC

Abstract

Context : Illness, accident or the amputation of an upper or lower limb has a major impact on a person's daily life. In recent years, so-called myoelectric prostheses have become increasingly popular as a means of compensating for the absence of a limb, particularly an upper one. The inputs to these prostheses are electrical signals delivered by muscles located upstream of the amputation. This thesis is part of the O2R "Organic Robotics" exploratory research program and equipment priority (PEPR). And more specifically, on the theme of "REINVENT" prosthetics, Reinventing prosthetics.

Subject :

In collaboration with the startup Orthopus, we have already worked on an under-actuated hand prosthesis (Butin et al 2023, 2024), for a wrist joint amputation. REINVENT would like to extend the study to an elbow/wrist/hand prosthesis. The intended application is therefore to take into account the handicap of an amputation upstream of the elbow. We will therefore address the problem of communication between the residual limb (RL) and the prosthesis actuators. This communication will focus on EMG associated with phantom mobility, present in 76% of lower limb amputees (Touillet et al. 2018). The thesis work will focus on three axes.

1°) Harnessing myoelectric activity for phantom mobility

Initially, transhumeral amputees will be selected and trained to have smooth phantom movements (Rossel, 2023) while performing voluntary movements of their RL. The muscular activities of the LR will be recorded with a dry multi-electrode sleeve (rapid installation), enabling us to study the minimum number of electrodes needed to distinguish between activities related to the execution of phantom movements and activities related to movements of the LR.
It will be necessary to learn how to dissociate the LR's own movements from the phantom movements of the amputated arm. In addition, wearing a prosthesis will induce disturbances linked to the movements of the last. These two phenomena will require the development of a robust

algorithm for detecting and identifying phantom movements. Learning methods (Lento, 2023) will be implemented to detect and identify, from multi-channel sEMG measurements, these phantom movements when the amputee participant wears the prosthesis on his LR.

2°) Regression-based myoelectric control and electrode arrays (LS2N):

Once we have separated the muscular activities associated with phantom movements from those linked to movements of the LR wearing the prosthesis, a descriptive model of the signals at LR level will be developed in order to extract parameters to characterize phantom movements.

3°) Prosthesis control.

In order to take into account possible disturbances acting on the mechatronic system, such as the effects of mechanical friction and gravity forces, and to obtain a continuous and dynamic behavior of the fitted arm, we will develop a set of compensations for the gravity of the mechatronic structure, its friction and its dynamics using a feed-forward control based on a dynamic model as realistic as possible (Aoustin and Formalskii, 2013).
Next, a study will be carried out to identify possible automatic behaviors of the prosthesis (resting postures, automatic adjustments, balancing) to reduce the cognitive load on users and reproduce reflex/unconscious activity.

Planning:

- Year D1 will be mainly devoted to exploiting myoelectric activities related to phantom mobility (writing a conference paper, biomechanics).
- In year D2, myoelectric control based on regression and electrode arrays (LS2N) will be developed (writing of a journal article).
- Year D3 will be devoted to mechatronic system control (writing of a journal article, writing of thesis).

Rossel O., M. Chateaux, N. Jarrassé, F. Vérité, A. Touillet, C. Nicol, J. Paysant, J. B. De Graaf ‘’ Phantom movement training without classifier performance feedback improves mobilization ability while maintaining EMG pattern classification’’ In IEEE Transactions on Medical Robotics and Bionics , volume 5 , 2023.

Butin C, Aoustin Y , Chablat D, et Gouaillier D, "Design of an efficient non-backdrivable mechanism with wrap spring for hand prosthesis", Journal of Mechanics and Robotics, 1-14, jMR-23-1557, 10.1115/1.4064739, 2024.

Aoustin Y. et Formaskii, A., "Modeling control and simulation of upward jump of a biped", Multibody System Dynamics, 32 (1), pp. 55-66, 2013.

Lento, B., Aoustin, Y., and Zielinska, T. (February 16, 2023). "Feasibility Study of Upper Limb Control Method Based On EMG-Angle Relation." ASME. J. Comput. Nonlinear Dynam. doi: https://doi.org/10.1115/1.4056918.

Touillet, A., Peultier-Celli, L., Nicol, C., Jarrassé, N., Loiret, I., Martinet, N., ... & De Graaf, J. B. (2018). Characteristics of phantom upper limb mobility encourage phantom-mobility-based prosthesis control. Scientific Reports , 8 (1), 15459.

Keywords: Upper limb prosthesis, phantom movements, intuitive control

The PHD proposal is governed by a 3-year doctoral contract (CDE).

Salary (2023): 26.4k€ gross

Start date and duration: The doctoral thesis will start ideally before 2024 for a duration of 36 months.

Workplace: The PhD student will carry out his/her research work at LS2N, Campus Ecole Centrale de Nantes (Nantes)

Application site : https://theses.doctorat-bretagneloire.fr/mastic

CV Phd Director

1. **Identification**

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1. **Research topics**

Walking robot, Exoskeleton, Processing of EMG signals, biomecanics**.**

2. Several publications

3. T. Yu, K. Akhmadeev, E. Le Carpentier, Aoustin Y., R. Gross, Y. Pereon, and D. Farina. Recursive decomposition of electromyographic signals with a varying number of active sources: Bayesian modelling and filtering, IEEE Trans. on Biom. Engi., Vol. 67, (2), p 428.-440, 2020.
4. T. Yu, K. Akhmadeev, E. Le Carpentier, Aoustin Y., and D. Farina. On-line recursive decomposition of intramuscular EMG signals using GPU-Implemented Bayesian Filtering, IEEE Transactions on Biomedical Engineering, Vol. 67, (6), pages 1806-1818, 2020.
5. K. Akhmadeev, T. Yu, E. Le Carpentier, Aoustin Y., and D. Farina. Simulation of motor unit action potential recordings from intramuscular multichannel scanning electrodes, IEEE Transactions on Biomedical Engineering, Vol. 67, pages 2005-2014, (7), 2020.
6. C. Chevallereau, P. Wenger, Aoustin Y., F. Mercier, N. Delanoue, and P. Lucidarme. Leg design locomotion with mono-articular, Mechanism and Machine Theory, Vol. 156, \\https://doi.org/10.1016/j.mechmachtheory.2020.104138, 2020.
7. L. Michel, S. Selvarajan, M. Ghanes, F. Plestan, Aoustin Y., J.~P.~Barbot, An experimental investigation of discretized homogeneous differentiators: pneumatic actuator case, Journal of emerging and selected topics in industrial electronics (JESTIE), Vol 2, (3), 227-236, DOI 10.1109/JESTIE.2021.3061924, 2021.
8. M. Hobon, De-Léone-Gomez V., G. Abba, {\bf{Aoustin Y.}}, and C. Chevallereau. Feasible Speeds for Two Optimal Periodic Gaits of a Planar Biped Robot, Robotica, 40(2), 377-402. doi:10.1017/S0263574721000631, 2022.
9. A. Kalouguine, V. De-Leon-Gomez, C. Chevallereau, S. Dalibard, Aoustin Y., "A new human-like walking for the humanoid robot Romeo, Multibody System Dynamics, DOI: 10.1007/s11044-021-09805-w, 2021.
10. T. Yu, K. Akhmadeev, E. Le Carpentier, Aoustin Y. and D. Farina, "Highly accurate real-time decomposition of single channel intramuscular EMG," in IEEE Transactions on Biomedical Engineering, Vol 69, (Issue 2), 746-757, doi: 10.1109/TBME.2021.3104621, 2022.
11. Côme Butin, Damien Chablat, Yannick Aoustin et David Gouaillier "Design of a Two-Speed Load Adaptive Variable Transmission for Energetic Optimization of an Accessible Prosthetic Hand", ASME, Journal of Mechanisms and Robotics, 2022.
12. Yaodong Lu, Yannick Aoustin et Vigen Arakelian "Mechatronic design of Dynamically Decoupled Manipulators based on Improvement", Robotica, https://doi.org/10.1017/S0263574722001485, 2022.
13. Qiuyue Luo, Christine Chevallereau, Yongsheng Ou, Jianxin Pang, Victor De-Leon-Gomez, Yannick Aoustin "A self-stabilised walking gait for humanoid robots based on

the essential model with internal states", IET Cyber-Systems and Robotics, https://doi.org/10.1049/csy2.12071, 2022.
14. Côme Butin, Damien Chablat, Yannick Aoustin et David Gouaillier, "Novel Kinematics of an Anthropomorphic Prosthetic Hand Allowing Lateral and Opposite Grasp with a Single Actuator", Journal of computational and nonlinear dynamics, CND-22-1260 https://doi.org/10.1115/1.4056852, 2023.
15. Lento, B., Aoustin, Y., and Zielinska, T. (February 16, 2023). "Feasibility Study of Upper Limb Control Method Based On EMG-Angle Relation." ASME. J. Comput. Nonlinear Dynam. doi: https://doi.org/10.1115/1.4056918.
16. Côme Butin, Damien Chablat, Yannick Aoustin et David Gouaillier, "Novel Kinematics of an Anthropomorphic Prosthetic Hand Allowing Lateral and Opposite Grasp With a Single Actuator", Journal of Computational and Nonlinear Dynamics 18 (6), 061005, 2023.
17. Mojallizadeh, M. R., Brogliato, B., Polyakov A., Sevarajan, S., Michel, L., Plestan, F., Ghanes, M., Barbot, J.~P., and Aoustin Y. "A survey on the discrete-time differentiators in closed-loop control systems: Experiments on an electro-pneumatic system." Control Engineering Practice 136(9):105546, 10.1016/j.conengprac.2023.105546.
18. Michel, L., Métillon, M., Caro, S., Ghanes, M., Plestan, F., Barbot, J.~P., and Aoustin Y. "A semi-implicit homogeneous discretized differentiator based on two projectors: Experimental validation on a cable-driven parallel robot named CRAFT." Mechanics \& Industry, Vol. 2024, 10.1051/meca/2024005.
19. Côme Butin, Yannick Aoustin, Damien Chablat, et David Gouaillier, "Design of an efficient non-backdrivable mechanism with wrap spring for hand prosthesis", Journal of Mechanics and Robotics, 1-14, jMR-23-1557, 10.1115/1.4064739, 2024.
20. Yaodong Lu, Yannick Aoustin}} et Vigen Arakelian "Optimization of design parameters and improvement of human comfort conditions in an upper-limb exosuit for assistance", Mutibody System, 10.1007/s11044-024-09977-1, 2024.