PhD Offer: **Design and development of a haptic simulator for learning spasticity treatments**

Duration :	36 months (Sept. 2024-Sept. 2027)
Funding :	ANR HASPA
Salary :	~2250 € gross / month (+ supplement if teaching duties)
Fields :	Robotics, Mechatronics, Automation
Laboratories :	Ampère (http://www.ampere-lab.fr/) - INSA Lyon SYMME (https://www.univ-smb.fr/symme) - USMB Annecy
Doctoral school :	Ecole doctorale EEA de Lyon (ED 160 EEA) INSA Lyon, University of Lyon
Encadrants :	Richard Moreau (richard.moreau *[at]* insa-lyon.fr) Luc Marechal (luc.marechal *[at]* univ-smb.fr)
Mots clés :	Medical robotics, mechatronic design, haptics, physiotherapy, spasticity

Scientific scope and context

This project is in the field of medical robotics, and more precisely in haptic simulation for the learning of physiotherapy techniques. It meets the requirements of the High Authority of Health: "Never the first time on a patient".

Spasticity is a condition in which muscles stiffen or tighten, preventing normal fluid movement. The muscles remain contracted and resist being stretched, thus affecting movement and gait. This condition affects an estimated 15 million people worldwide. Spasticity, in combination with other symptoms, can increase pain and significantly reduce mobility in people with neurological diseases [Brown, 1994]. To assess the severity of this symptom, the degree of resistance to rapid movement is evaluated using the Modified Ashworth Scale (MAS), which is the most universally used clinical tool [Bohannon, 1987].

The diagnosis consists of assigning a relevant MAS score when mobilising limb joints in manual therapy. The training is currently done by companionship with injured patients. In addition to the ethical problems that this type of training raises, the degree of spasticity may change during the diagnostic evaluation session (thus modifying the patient's MAS score), which makes it even more difficult to transmit the know-how. At present, there are no simulators to train this technique.

To answer this need, the HASPA project, financed by the ANR, aims at developing a haptic simulator of the lower limb to propose an innovative tool for the learning the training of practitioners.

Aim of the thesis

The main objective of the thesis is to design and prototype a physical haptic simulator allowing to simulate different cases of spasticity and thus giving young practitioners the opportunity to train without risk. Within the framework of this PhD, it is thus a matter of designing a lower limb with 3 degrees of freedom reproducing the ankle, the knee and the hip. This prototype will have to integrate sensors and actuators in order to reproduce the spastic behaviour of the muscles.

Scientific challenges

- Establish a set of specifications in collaboration with healthcare experts.
- Design and control a haptic interface reproducing the lower limb in stiffness.
- Pilot the prototype to simulate the different cases of spasticity.
- Generalise the methods used with the aim of designing an upper limb simulator.

Expected original contributions

- Propose a high-performance haptic simulator with innovative actuation
- Implement pedagogic exercises

Research programme and proposed scientific approach

Mechatronic design: Following an analysis of the professional activity of the practitioners carried out by some of the HASPA project partners, a set of specifications will have to be drawn up. This step consists in defining how to represent technologically (mechanical systems, actuators, sensors...) the necessary or desired functionalities on the simulator to allow a relevant learning and to record the performed gestures.

The overall design of the physical simulator of a lower limb must be carried out. This will involve designing a host mechanical structure for the integration of actuators and sensors, and organising the fabrication of the external envelope that represents a lower limb by using rubber-like materials.

Control: As regards actuation, two approaches are envisaged. The first concerns the use of pneumatic muscles to control the different segments of the lower limb. The interest of pneumatic muscles lies in their low mass/power ratio and in their anthropomorphic shape. They will be driven in an antagonistic manner in order to control the stiffness of the joints. The second approach consists in designing a hybrid actuator integrating both a magneto-rheological brake (developed by one of the project partners) and a pneumatic or electric actuator in order to control the compliance of the system and take advantage of the benefits of each.

Experimental **Validation:** Finally, the last part of the PhD will be dedicated to a measurement campaign to be carried out at the Hospices Civils de Lyon (HCL) in order to test the prototype in situ as a learning simulator. Tests will be conducted with expert and novice practitioners in order to record the gestures performed by these two populations. The analysis of the data should make it possible to define criteria which will be linked to the learning curve of the gesture and which will have to differentiate these 2 populations.

Workplace:

This work will be carried out in 2 mechatronics laboratories. The design part will be carried out mainly in collaboration with SYMME laboratory (https://www.univ-smb.fr/symme/) located at the University Savoie Mont Blanc in Annecy and the control part will be carried out mainly at the Ampère laboratory (http://www.ampere-lab.fr/) at INSA in Lyon. Finally, the measurement campaign will also be carried out in Lyon on the Movement & Disability platform of the Henry Gabrielle Hospital, which is a partner in the project.

External Collaborations : CEA-List / HCL

Candidate profile:

Master's degree or engineering degree in Robotics, Mechatronics, Mechanical Engineering with a specialisation in automation or in a field that concerns the design, modelling and development of systems for the medical sector.

Proficiency in SolidWorks or Catia (or equivalent) is required as well as instrumentation skills. Modelling skills are desired and programming in MATLAB or Python will be appreciated.

Application:

Applications should be sent to the supervisors by e-mail, indicating "HASPA PhD Application" in the subject line.

The file should contain the following documents:

- a detailed CV,
- a letter of application explaining the motivations for undertaking a thesis, addressing the proposed subject and showing the links between the candidate's profile and the themes of the thesis subject,
- transcripts (Bachelor's degree, Master's degree and first semester of Master's degree or engineering school)
- letters of recommendation or, failing that, the names of people in the field of academic research who recommend the candidate.

Literature references

[Bohannon, 1987] R. Bohannon, M. Smith. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther., 1987, 67(2):206-207

[Brown, 1994] Brown P., Pathophysiology of spasticity. Journal of Neurology, Neurosurgery & Psychiatry, 1994, 57:773-777.