Université Lille Nord de France
Pôle de Recherche et d'Enseignement Supérieur

Ecole doctorale régionale Sciences Pour l'Ingénieur
Lille Nord-de-France - 072

PhD Title: **Algebro-differential approach for the nonlinear control of robotic systems in physical interaction with humans**

Funding: CDD 3 years at University of Valenciennes

Start date : september 2018

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Keywords:
Robot manipulator, collaborative robotics, haptics, kinesthetic feedback, impedance / admittance control, nonlinear dynamics, algebro-differential model, Takagi-Sugeno fuzzy system, robust control, Lyapunov method, LMI (linear matrix inequalities).

Description:

The physical interaction between humans and controlled systems appears in a very wide variety of applications. It appears in various features that are expected to develop in the context of robotic assistance, rehabilitation, substitutive methods for improving motor function, interfacing with a virtual or remote object... The control of this physical interaction is of particular importance in terms of safety (of the person), functionality (to ensure the expected service actually), fatigue and comfort for the user. This issue appears directly in the use of systems such as tele-operative surgical robots, haptic interfaces with a virtual environment, active orthoses, exoskeletons and collaborative industrial robots (cobots) for example. In these systems interacting physically with humans, functionality relies on one or more physical contacts between an active system and humans. A contact is the seat of energy exchange between the human and the system. Furthermore, it imposes kinematic constraints in order to provide kinesthetic information and / or motor assistance to a person in a variable configuration (configuration constraints in the workspace). The system control must guarantee in any situation the stability during the interaction (stability established from the variables of velocity and force involving in the contact). In addition, it must ensure the continuity of service during the changes of configurations, in particular when the contact is established or, conversely, when the contact breaks down.

In order to address the issue of the physical interaction of a controlled system with humans, the goal of this thesis is to develop new theoretical tools intended to be applied in the main research topics of the LAMIH around automatic control and mechanics for humans and, in particular, biomechanics and disability. The research subject is based on an algebro-differential approach of the mechanical modeling of the interaction with humans. In the thesis of B. Allouche [1], the interest of this approach has been shown for the PDC control of parallel robotic manipulators with algebraic constraints inherent to their kinematic architecture. This approach has notably reduced the complexity of the Takagi Sugeno model used for control synthesis. The goal is to develop this approach in the case of variable configuration of kinematic constraints and to use the additional variables introduced by the algebro-differential approach to estimate the contact forces.

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The goal is to develop tools based on TS models built from the algebro-differential approach to ensure stability in the different situations of physical interaction considered. An extension in descriptor form should be able to handle the singular cases. In addition, the interaction specifications (to ensure the expected functionality: kinesthetic feedback, motor assistance, rehabilitation of a gesture...) via reference models are to be developed in order to introduce additional criteria for control synthesis. An experimental phase is also expected in order to validate the approach [2] (cf. fig. 1-2).

[1] ALLOUCHE B., DEQUIDT A., VERMEIREN L., DAMBRINE M. (2017). Modeling and PDC fuzzy control of planar parallel robot: A differential– algebraic equations approach. International Journal of Advanced Robotic Systems, 14 (1).
[2] DANG Q., VERMEIREN L., DEQUIDT A., DAMBRINE M. (2016). Experimental study on the stability of an impedance-type force-feedback architecture based on an augmented-state observer for a haptic system under time delay using a LMI approach. Proc IMechE Part I: Journal of Systems and Control Engineering, 230(1), pp. 58-71.

Skills / Candidate profile:

Master's degree or engineer with a very good background in automatic control (linear and nonlinear dynamics, robust control, linear matrix inequalities...).
Good background in robotics, mechanical modeling, mechatronics, real-time implementation will be appreciated.
Excellent command in written English.
Advanced level in Matlab programming and model development on Simulink.

Candidature:

Interested candidates must send the following material:
- a detailed CV
- results in Master1 and Master2 or engineering school and class ranking
- name of referees and recommendations letters (if any)

to
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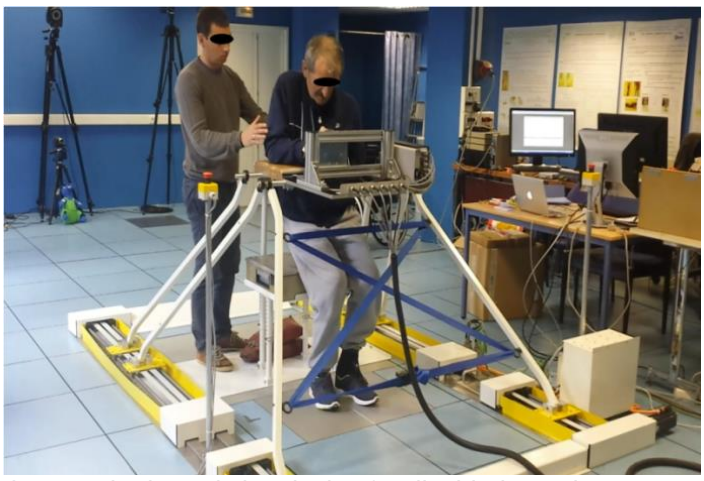
Fig. 1. Robotic assistive device for disabled people

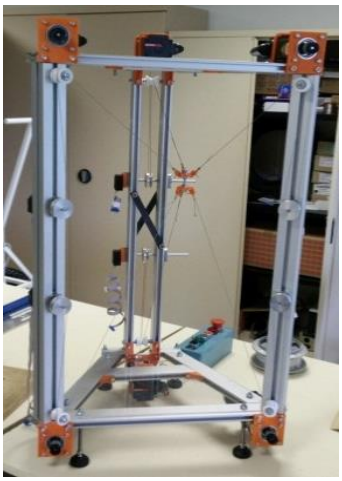
Fig. 2. Haptic interface device