PhD Proposal 2017

School: Ecole Centrale de Nantes	
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Collaboration with other partner during this PhD: **In France:**	**In China:**

Title: Design and Control of Low-Impedance Mechanical Interfaces for Human-Machine Physical Interaction
Scientific field: Automation and Robotics
Key words: human-machine interaction, robotics, drones, mechanical design, dynamic balancing, impedance control

Details for the subject:

Background, Context:

Smart machines are going to be a strong axis of development for the Industry 4.0. Robots, drones, intelligent vehicles and many other machines, will be in close contact with humans, and there is a need to make the physical interactions between the machines and the human beings safe.

This issue was raised about two decades ago (see for instance [1]), which led to several concepts that aim at developing inherently safe robots for physical human-robot interactions [2]–[4]. A current trend is now to address the same problem with drones.

These safety issues and the inherent high impedance of the commercial robots/drones make it difficult to rely on them for any human-machine cooperation.

It was recently proposed in [5] to extend the principle of macromini manipulator by including two carefully designed clusters of joints that have drastically different impedances in order to provide the most intuitive and effortless interaction. The macromini concept was first investigated in [6][7] for fully actuated manipulators in order to reduce the effective inertia at the end-effector. More recently, this low-impedance principle was further developed by replacing the active mini manipulator with a passive mechanism [8][9]. More specifically, the macro component — which is the portion of the manipulator directly attached to the fixed base— consists of high-impedance active (HIA) joints and the mini component — which is the part close to the end-effector — consists of low-impedance passive (LIP) joints. The HIA joints provide the payload handling capability while the LIP joints provide the low-impedance interaction with the human operator.

The resulting architecture yields large payload and extensive workspace capabilities, end-effector agility and responsiveness, and safety at all times.

However, there are limitations to the proposed architecture:

- it is bulky and heavy. Thus it cannot be put on autonomous systems whose energetic / payload capacity is limited, such as drones
- it was designed for translational systems, and cannot be used on machines whose end-effector rotates.

Research subject, work plan:

The objective of the research work is to design and control new low-impedance mechanical interfaces for human-machine physical interaction, which can avoid the aforementioned drawbacks of the previous system. For that, we need to:

1. work at the preliminary design stage [10] in order to synthesis mechanism architecture potentially able to perform the desired performance
2. optimize the dimensions and the mass repartition of the system [11] in order to make it able, for instance, to reach a specified workspace, lightweight but stiff enough, etc.
3. near optimal balancing balancing techniques [12] will be used in order to be sure that, when the user is no more touching the interface, the interface will passively come back alone to its neutral configuration so that the machine can stop, whatever the spatial configuration of the end-effector on which is mounted the interface
4. define an adequate impedance controller

Two main user-cases will be treated which are designing an interface for human-machine physical interaction

- in the case of a 6 degrees-of-freedom (dof) industrial robot
- in the case of a drone quadcopter

The last part of the work will be to validate the results by simulations (ADAMS + Simulink) and then via experimentations.

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